Ornamental Plants

Annual Reports and Research Reviews • 1998

THE OHIO STATE UNIVERSITY
OARDC

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EXTENSION

January 1999
Special Circular 165
Ohio Agricultural Research and Development Center
In Partnership With Ohio State University Extension

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Ornamental Plants
Annual Reports and Research Reviews
1998

Edited By

Mary Ann Rose
and
James A. Chatfield

Ohio Agricultural Research and Development Center
Ohio State University Extension
Department of Horticulture and Crop Science
The Ohio State University

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Cover Photo: Ken Cochran is shown among the umbrella magnolias *(Magnolia tripetla)* at the Secrest Arboretum on the Ohio Agricultural Research and Development Center's Wooster campus.

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Contents

Ohio State University Extension Nursery, Landscape, and Turf Team Directory: 1999

Our Vision

The vision of the Extension Nursery, Landscape, and Turf Team is to serve as the University's partner with the green industry to position us for the future.

Our Mission

The mission of the Extension Nursery, Landscape, and Turf Team, through our interdisciplinary and industry partnerships, is to improve the process of acquisition, delivery, and support of accurate, practical, and timely educational resources.

An Invitation

Membership on the team is based on interest and commitment to the vision and the mission of the team. Potential members are encouraged to participate in some of the activities to determine if they would like to become a part of the team. Individuals who are interested in the work of the team should contact any of the team members.

Directory developed by Jack Kerrigan, Ohio State University Extension, Cuyahoga County.

Team Members

Charles Behnke

- Diagnosis of cultural problems of trees and shrubs
- Weed identification
- Insect identification
- Greenhouse management
- Garden center employee training
- IPM

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- Consumer and environmental horticulture
- Garden center management
- Landscape ornamentals
- Landscape maintenance
- Communications
- Master Gardener Program

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- Turfgrass culture and diseases
- Plant and weed identification
- Herbicide damage on crops and ornamentals
- Homeowner herbicide information

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Joe Boggs

- Ornamental entomology
- Landscape management
- Turf management
- Tree nursery management
- Urban forestry
- Diagnosis of plant problems
- IPM
- Christmas tree production

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Jim Chatfield

- Diagnosis of plant problems
- Plant disease control
- Ornamental plant selection
- Plant pest monitoring
- IPM

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Assistant State Specialist, Landscape Horticulture
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Ken Cochran

- Taxonomy and classification of ornamental plants
- Plant selection for environmental enhancement
- Landscape management
- Nursery operations and management
- Plant propagation

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Erik Draper

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- Landscape maintenance
- IPM
- Tree and small fruit management

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David Dyke

- Horticultural marketing

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Denise Ellsworth

- Pest diagnosis
- IPM in the landscape
- Master Gardener Program
- Youth gardening, garden design, and teacher training

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Gary Gao

- Tree fruits and small fruits
- Plant and soil nutrition
- Consumer horticulture
- Garden center employee training
- Plant physiology

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- Integrated pest management
- Phenology

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Harry A. J. Hoitink

- Composting
- Compost-amended substrates to control disease

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Jack Kerrigan

- Consumer and environmental horticulture
- Landscape design and plant selection
- Diagnosis of landscape cultural problems
- Communications for media
- Master Gardener Program

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Charles R. Krause

- Plant disease management
- Application technology research
- Spray drift
- Abiotic disease diagnosis
- Cultivar identification of nursery and greenhouse crops

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USDA, Agricultural Research Service
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- Turf and landscape diagnoses

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- Integrated pest management

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- Consumer and environmental horticulture
- Landscape ornamentals and maintenance practices
- Landscaper/homeowner conflict resolution
- Communications for media
- Master Gardener Program

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- Turfgrass fertility
- Turfgrass weed control
- Turfgrass selection and establishment

- Turfgrass growth regulators
- Turfgrass culture (aerification, irrigation, and mowing)
- IPM

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Tim Rhodus

- Management
- Economics
- The Internet

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- Turfgrass management
- Turfgrass disease diagnosis
- Turfgrass patch diseases
- Landscape management
- Diagnosis of landscape problems
- IPM

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Marianne Riofrio

- Volunteer management
- Vegetable gardening
- Yard and garden IPM

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- Nutrition and fertilizers
- Nursery container production
- Weed control in ornamentals
- Water, media, and soil testing

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Dave Shetlar

- Ornamental tree and shrub entomology
- Turfgrass entomology
- Christmas tree entomology
- Pest monitoring and detection
- IPM

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Tom Shockey

- Garden center employee training
- Department of Horticulture and Crop Science intern placement
- Consumer horticulture
- Youth gardening project evaluation

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Amy Stone

- Consumer and environmental horticulture
- Green industry training (NW Ohio)
- Landscape maintenance practices
- Master Gardener Program

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John Street

- Turfgrass management
- Turfgrass fertilization
- Turfgrass weed control
- Fate of pesticides and nitrogen in turf

Turfgrass Extension Specialist
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Nancy Taylor

- Diagnosis of plant diseases
- Diagnosis of ornamental, tree, and shrub diseases
- Coordinator of the C. Wayne Ellett Plant and Pest Diagnostic Clinic

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Randy Zondag

- Commercial nursery production (field and container, fertility, pesticide, safety, and water quality)
- Landscape installation and maintenance
- IPM
- Soils
- Greenhouse management
- Fruit production

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During the growing season, the team teleconferences weekly and develops a newsletter called the *Buckeye Yard and Garden Line*, which is available by a fax subscription service (contact a local team member) or on the World-Wide Web at:

http://www.hcs.ohio-state.edu/hcs/hcs.html

Ohio State University Department of Horticulture and Crop Science, "Horticulture and Crop Science in Virtual Perspective"

Buckeye Yard and Garden Line Fax Centers

Clark County	Pam Bennett
Cuyahoga County	Jack Kerrigan
Franklin County	Jane Martin
Hamilton County	Joe Boggs
Lake County	Randy Zondag
Lawrence County	Dave Dyke
Montgomery County	Pete Lane

Floriculture Industry Roundtable of Ohio: 1999

Our Mission

The mission of the Floriculture Industry Roundtable of Ohio is to provide an educational forum to Extension, growers, and allied industries across the Midwest region, currently including Ohio, Michigan, Pennsylvania, Kentucky, and Indiana, for the exchange, discussion, and dissemination of information related to floriculture.

Roundtable Resources and Team Members

Greenhouse Management

Behnke, Charles
Everett, Craig
Gao, Gary
Kneen, Hal
Krauskopf, Dean
McMahon, Peg
Moll, Norm
Pasian, Claudio

Plant Pathology

Ellsworth, Denise
Hoitink, Harry
Nameth, Steve
Taylor, Nancy

Entomology

Cloyd, Raymond
Lindquist, Dick
Steele, Julie

Food, Agricultural, and Biological Engineering/Greenhouse Environment

Ling, Peter
Short, Ted

Management and Economics

Kneen, Hal
Rhodus, Tim

Composting

Hoitink, Harry

Crop Physiology

Carver, Steve
McMahon, Peg
Metzger, James
Pasian, Claudio

Nutrient Analysis/Water Quality

Carver, Steve
Krauskopf, Dean
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Watson, Maurice

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- Production/postproduction physiology
- Plant nutrition
- Greenhouse management

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- Integrated pest management in greenhouse crops
- Use of biological controls
- Testing of new products

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- Integrated pest management
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- Greenhouse management

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- Composting
- Potting mixes/container media formulation
- Biocontrol of plant diseases

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- Greenhouse management
- Small business management
- Production economics
- Marketing

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- Greenhouse crop nutrition
- Foliar and media analysis
- Greenhouse crop management
- Greenhouse rose production

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- Greenhouse plant growth control systems
- Digital image applications

Lindquist, Richard

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- Integrated Pest Management of greenhouse crops
- Testing of products, equipment, "beneficials"

McMahon, Margaret (Peg)

Assistant Professor
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Columbus, OH 43210
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- Floriculture crop physiology
- Light quality regulation of crop development
- Greenhouse management
- Production of floriculture crops

Metzger, James (Jim)

Professor and D. C. Kiplinger Chair
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- Role of hormones in plant growth and development
- Environmental control of flowering
- Use of biotechnology to improve floricultural crops

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- Greenhouse management

Nameth, Steve

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- Diseases of floral crops: identification, control, and management
- Identification and characterization of viruses of floral crops

Pasian, Claudio

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- Crop eco-physiology
- Production and management
- Modeling and timing of floricultural crops

Rhodus, Tim

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- Management and economics of horticultural crops
- Multimedia applications for marketing and education

Short, Ted

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- Greenhouse system design for optimum production
- Evapotranspiration of greenhouse crops
- Solar energy systems
- Mechanization of horticultural crops

Steele, Julie

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- Insect identification and control recommendations

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- Diagnosis of plant diseases, all crops

Watson, Maurice

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- Analysis of soil, soilless mix, sewage sludges, manures, and water
- Water quality, composting, and environmental pollution problems

Ohio State University Extension
Buckeye Yard and Garden Line

Gary Y. Gao, Pamela J. Bennett, Joseph F. Boggs, James A. Chatfield, David E. Dyke, Jane C. Martin, David J. Shetlar, and Randall H. Zondag

Summary

The *Buckeye Yard and Garden Line (BYGL)* is one of the key ways through which Ohio State University Extension and the Extension Nursery Landscape and Turf Team (ENLTT) provide ornamental-plant and plant-problem information to the green industry, to Extension offices, and to the general public. This article answers some questions about *BYGL* and provides the results of the 1998 *BYGL* Evaluation Survey.

What Is *BYGL?*

The *Buckeye Yard and Garden Line (BYGL)* is a weekly plant update in the form of an electronic newsletter. It is written by OSU Extension agents and specialists, from a conference call held every Tuesday from April–October. *BYGL* is funded by the Ohio Nursery and Landscape Association and OSU Extension, with additional contributions from the Ohio Chapter of the International Society of Arboriculture.

Who Is *BYGL*'s Audience?

BYGL is written for green industry professionals, Extension agents, Master Gardeners, and other horticulturists in Ohio and throughout the United States, especially the Midwest.

How Do You Receive *BYGL?*

There are three ways to receive *BYGL* — by e-mail, by fax subscription, and directly on the World Wide Web. Here's how:

- By e-mail: simply send your e-mail address to:

  chatfield.1@osu.edu

- On the World Wide Web: Access *Buckeye Yard and Garden onLine* on Ohio State University's Horticulture in Virtual Perspective:

  http://www.ag.ohio-state.edu/~bygl/

- For fax newsletter subscriptions: contact one of these Ohio State University Extension offices:

  ABE Center (NW Ohio)

  Amy Stone 419-354-6916

  Clark County

  Pam Bennett 937-328-4607

Gary Y. Gao, Ohio State University Extension, Clermont County; Pamela J. Bennett, Ohio State University Extension, Clark County; Joseph F. Boggs, Ohio State University Extension, Hamilton County; James A. Chatfield, Ohio State University Extension, Northeast District/Department of Horticulture and Crop Science; David E. Dyke, Ohio State University Extension, Lawrence County; Jane C. Martin, Ohio State University Extension, Franklin County; David J. Shetlar, Ohio State University Extension/Ohio Agricultural Research and Development Center/ Department of Entomology; and Randall H. Zondag, Ohio State University Extension, Lake County.

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Jane Martin	614-462-6700
Hamilton County	
Joe Boggs	513-825-6000
Lake County	
Randy Zondag	440-350-2269
Montgomery County	
Pete Lane	937-224-9654

Is There a Cost for *BYGL?*

Only the fax subscriptions have a fee ($35 a year) to cover phone line costs, and even fax subscriptions are free for members of the Ohio Nursery and Landscape Association, the Ohio Chapter of the International Society of Arboriculture, and the Ohio Turfgrass Foundation.

Where Can You Find the Time for *BYGL?*

Reading time during the growing season comes at a premium, and that is why *BYGL* is formatted in short bytes (one to two paragraphs) of the most relevant information on a particular topic. We also strive for a lively, user-friendly, sometimes humorous style.

What Is *Buckeye Yard and Garden onLine?*

This is the World Wide Web version of *BYGL,* and it comes not only with the text of *BYGL* available on the e-mail and fax versions, but also with hot links to color images of pests and plants and to more than 20,000 additional fact sheets from Ohio State and other universities.

What Is *BYGLive!?*

BYGLive! is a series of informal programs at arboreta throughout Ohio on the first Monday of each month, May–October. The participants have a chance to see plants and plant and pest development throughout the season at sites listed here, to do some diagnostic troubleshooting, and to provide observations and insights that will add to the next day's *BYGL* conference call. Sites for 1999, with key contacts, are:

- Cincinnati at Spring Grove Arboretum (starts in April)
  Joe Boggs
  513-825-6000

- Wooster at Secrest Arboretum
  Ken Cochran
  330-263-3761

- Toledo at Stranahan Arboretum
  Amy Stone
  419-354-6916

- Akron at Seiberling Naturealm
  (year-round on the first Monday of the month)
  Denise Ellsworth
  330-497-1611

What Were the Results of the 1998 *BYGL* Evaluation Survey?

Number of respondents = 220

Key to Responses:

SA	=	Strongly Agree
A	=	Agree
N	=	Neutral
D	=	Disagree
SD	=	Strongly Disagree
NA	=	Not Applicable

Evaluation Question 1:
***BYGL* was useful to my job and business.**

SA	=	125
A	=	85
N	=	7
D	=	0
SD	=	0
NA	=	3

Evaluation Question 2:
***BYGL* helped in answering clientele questions.**

SA	=	107
A	=	93
N	=	12
D	=	1
SD	=	0
NA	=	7

Evaluation Question 3:
***BYGL* was timely.**

SA	=	131
A	=	88
N	=	1
D	=	0
SD	=	0
NA	=	0

Evaluation Question 4:
I (we) changed some horticultural practices based on *BYGL*.

SA	=	26
A	=	102
N	=	62
D	=	5
SD	=	0
NA	=	25

Evaluation Question 5:
I (we) changed some pesticide-use practices based on *BYGL*.

SA	=	32
A	=	89
N	=	61
D	=	4
SD	=	0
NA	=	34

Evaluation Question 6:
***BYGL* has resulted in improved customer service in our company.**

SA	=	59
A	=	102
N	=	27
D	=	4
SD	=	0
NA	=	28

Evaluation Question 7:
Do you use *BYGL* in employee training?

Yes	=	102
No	=	50
NA	=	68

Evaluation Question 8:
How many people read *BYGL* from access to your subscription?

From 220 respondents = 1,340

Evaluation Question 9:
Has the information in *BYGL* saved your company money?

Yes	=	73
No	=	38
NA	=	109

Selected Suggestions and Comments from the Evaluation Survey

"BYGL saved me money because of better customer service, hence more sales."

— A Garden Center
in Summit County, Ohio

"The first week we did not receive the BYGL, several comments were made in the office that we are going to miss the helpful articles and the humor — maybe fax us a hort joke periodically over the slow winter months."

— A Green Industry Business

"It is a very useful tool — many times prompting me when to act about several pests I tend to overlook. Many thanks."

— Edson Tree Service
Allegheny, Pa.

"I have over 20 years experience in agriculture, and I still learn at least one or more things in every newsletter. Impressive."

— Stacey Butterfield
The Way International, New Knoxville, Ohio

"Thanks for the great info — helps us all feel connected. Your 'open door' for sound, solid info is like having a university on call all the time."

— Andy Spiller
Grounds Maintenance and Garden Center
Hamilton County, Ohio

"BYGL saved us money by using the correct control on pests at the proper time. Very helpful and very interesting newsletter."

— Dan Shaw
Winton Woods Maintenance, Cincinnati, Ohio

"More turf info needed. More info on poisonous plants would be helpful."

— Porathe Wilson
The Seven Hills School, Cincinnati, Ohio

"Great! Keep it up! We/I count on this weekly update. We consider it a part of our weekly training. I personally use it as 'possible' info for articles/TV tips! Timely tips."

— Ronald Wilson
Natorp Garden Center, Cinncinati, Ohio

"BYGL saved us money because it keeps us on top of any plant and disease problems. This allows us to better serve our clients."

— Ammon Landscape, Inc.
Boone County, Kentucky

"BYGL saved us money by having authoritative, timely, concise information, eliminating biased research with manufacturers and suppliers. Saving time and eliminating out-dated practices. You're doing an excellent job — but don't live on your laurels. Keep up the unbiased research and do keep industry members informed. Our future depends on your author research."

— Woody Wesig
Woody Tree Medic, Montgomery County, Ohio

"BYGL saved us money by informing us [when] the window of opportunity is present so that you did not spray too late or too early. I enjoy the info and the subtle humor."

— Jackie Suber
Wengerlawn Nursery Co.,
Montgomery County, Ohio

"BYGL saved us money through fine tuning pest-management programs."

— Bal Rao
Davey Tree Service, Kent, Ohio

"The information in BYGL saved our company because (employee training) is done by reading newsletters rather/in addition to traveling; answers questions before they are asked; saves time on phone calls to Extension services."

— Lowe's Greenhouse
Geauga County, Ohio

"We enjoy very much and appreciate the amount of effort required to consistently produce such in-depth, timely, and informative electronic newsletter."

— Bob Childs
University of Massachusetts Extension Service

"I appreciate the timeliness of the BYGL. Ohio is similar in timing and pests to Indiana, and I get a lot out of it. I especially like the fact that field agents are knowledgeable enough to actually know what they are seeing. I especially like the background information on the pests (life cycle, historical significance, etc.). I most enjoy the comraderie that Ohio Extension staff have — although I miss many of the inside jokes, it's nice to know that y'all have a sense of humor. Keep up the good work! I look forward to next spring's edition."

— Larry Caplan
Extension Educator, Purdue University

"Please keep up the good work."

— David Hensley
University of Hawaii

"I love the comments and timeliness. It helps me show my students that not all plant professionals are dry humorless workaholics."

— Daniel Rueger
Ashland High School, Ashland, Ohio

"I like the wit and humor that goes with BYGL; it makes reading it fun as well as informative. I would like to see more emphasis on disease and insect identification and diagnostics."

— Chris Vild
Service Director for
City of University Heights, Ohio

"I particularly like the light-hearted writing approach; I think it really helps make the information understandable (and palatable). We use you as an early warning device. Even though some of the pests and problems you have will never reach us, many of them do show up a bit later, so we're more prepared."

— Deborah Brown
University of Minnesota

"BYGL was very useful in creating timely news columns and newsletters. We changed pesticide practices because we were able to offer alternatives to clientele. BYGL has resulted in improved customer service since we increased timeliness in working with clientele and answering questions."

— Robert Moore
Ohio State University Extension,
Fairfield County

"BYGL saved us money because we use less chemicals now. Thanks a lot for all of your efforts this year. BYGL helped us a lot at Xavier University maintaining the grounds."

— Jim Caldwell
Xavier University, Cincinnati, Ohio

"The BYGL might be improved if it was a bit shorter — you know how we all get swamped with reading material these days. The observation of when pests are 'hatching' is super-helpful, and pesticide recommendations and timing are too."

— Donnan, Landscape Contractor
Washington County, Pennsylvania

"I would like to see more information on how to grow different species of plants. This should contain information on how to propagate, fertilize, prune, water, overwinter, and [solve] disease and insect problems. The information should be specific to container and field growing. A good time to present this information is when a problem pertaining to a certain species is directed to one of the members of your team."

— Ken Ewing
New Richmond, Ohio

"Please be more thorough with weather updates, give weekly rainfall totals for regions, soil temperature, etc. Maybe a way to access some highs and lows for temps from the week."

— A Landscape Design and
Maintenance Firm
Cuyahoga County, Ohio

"Another great year!! I'm not sure what I would do without the BYGL."

— Manbeck Nurseries Inc.
New Knoxville, Ohio

Micronutrient Sources for Container Nursery Plants

Mary Ann Rose and Hao Wang

Summary

Commercial micronutrient fertilizers and a biosolids compost were used in the production of container *Rhododendron* 'Girard Scarlet.' In some cases, using a micronutrient fertilizer or a compost-amended medium resulted in higher micronutrient concentrations in the potting medium or in plant foliage. However, there were no visible differences in plant size, color, and quality among controls, which received no micronutrient source, and the other treatments. Analysis of the bark-based medium suggested that the bark may have supplied sufficient micronutrients for a full year.

Introduction

In the 1960s, soilless growing media were first developed to replace the use of soil mixes in container production. These new lightweight media were an improvement over heavy, soil-containing media because they did not require steam sterilization and had greatly improved physical characteristics, in particular, superior air capacity. However, soilless-medium components had a much lower capacity to store and supply nutrients than soil-containing mixes; because of this, slow-release fertilizers were developed to maintain a constant supply of N, P, and K. Micronutrient fertilizers also were developed to be used with soilless media to supply trace elements formerly supplied by soil. Many growers use these micronutrient fertilizers today.

Research with biosolids compost (Ticknor *et al.*, 1985) and pine bark (Niemiera, 1992; Wright and Hinesley, 1991) has suggested that micronutrient fertilization may be unnecessary when those materials are used as growing-medium components. Even phytotoxic levels of micronutrients may be found in some types of medium components; for example, hardwood bark may contribute toxic levels of Mn (Bunt, 1988; Svenson and Witte, 1992), and compost may have high levels of B (Lumis and Johnson, 1982; Rosen *et al.*, 1993). However, some researchers have found that the micronutrient supply from medium components is insufficient (pine bark: Handrek, 1995; Whitcomb *et al.*, 1975) and that micronutrient fertilizer addition may improve growth (Wright *et al.*, 1997).

Although previous research does not consistently support the need for micronutrient fertilizer supplements in soilless media, manufacturers are nonetheless producing an increasing number of slow-release fertilizers with minors packages (slow-release N-P-K + minors products). Micronutrients in these products may be bulk-blended with N-P-K prills, or may occur within, or as part of, the prill coating (Brian Birrenkott, The Scotts Co., personal communication). In a preliminary experiment (Rose, unpublished), mi-

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cronutrient availability from several of these products and a stand-alone micronutrient fertilizer (Micromax, The Scotts Co., Marysville, Ohio) was examined. One of the slow-release + minors fertilizers and the Micromax fertilizer increased dry weights relative to controls that received no supplemental micronutrient fertilizer. However, significant growth effects were observed on only one of four sampling dates and for one species (*Rhododendron*). Foliar micronutrient concentrations were not different among treatments at any date. Overall, the preliminary research did not strongly support the use of micronutrient fertilizers in soilless media.

The primary goal of this experiment was to determine whether typical sources of micronutrients used in container nursery production supplied micronutrients over a full year, and whether they improved growth of container *Rhododendron*. Biosolids compost was used as a micronutrient source in one treatment; all other sources were commercial fertilizers.

Materials and Methods

Four-inch-square potted liners of *Rhododendron* 'Girard Scarlet' were potted June 7, 1996, in trade two-gallon (6.1 liter) pots containing a 3:1:1:0.2 ratio by volume of pine bark, hardwood bark, peat, and sand. The medium was amended with gypsum, dolomitic lime, and granular sulfur at 4, 2, and 1 lb. per cubic yard, respectively. The micronutrient treatments consisted of:

1. Control: No added micronutrients, fertilized with Osmocote 18-6-12.
2. Biosolids compost as a source of micronutrients, fertilized with Osmocote 18-6-12; Technagro Compost (Kurtz Bros., Inc., Cuyahoga Heights, Ohio) was incorporated at 15% by volume.
3. Step HiMag (stand-alone micronutrient fertilizer) topdressed at 1.5 lbs./cu. yard, fertilized with Osmocote 18-6-12.
4. Customblend 19-5-8 (a slow-release-plus-minors fertilizer).
5. Sierra 17-6-10 (a slow-release-plus-minors fertilizer).
6. Osmocote Plus 16-8-12 (a slow-release-plus-minors fertilizer).
7. High N Plus 22-4-8 (a slow-release-plus-minors fertilizer).
8. Nutricote Plus 18-6-8 (a slow-release-plus-minors fertilizer).

All plants were top-dressed with 3.8 grams nitrogen (2 lbs. N per cubic yard) from either the 18-6-12 (no micronutrient package) or the slow-release + minors fertilizers. All slow-release fertilizers were eight- to nine-month release formulas.

Table 1 presents how much manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and boron (B) was supplied to each pot in each treatment. The amounts vary widely because it is impossible to equalize amounts applied from sources that contain micronutrients in varying proportions. Our decision was to instead hold constant the amount of nitrogen applied from each slow-release product. The stand-alone product, Step Hi-Mag, was used at the labeled rate, and it is clear that this product supplies a much higher level of micronutrients than the slow-release-plus minors products applied at typical nitrogen fertilization rates (Table 1). There is no guaranteed micronutrient analysis for Technagro compost, but the authors tested the material and report the test results in Table 1. The compost supplied about twice as much Fe and Zn as the Step Hi-Mag.

There were 18 single-plant replications of each treatment, divided between three blocks. Recently matured leaves were sampled for foliar analysis a year after potting on June 1, 1997. The growing medium was sampled for nutritional analysis twice — Sept. 12, 1996, and May 27, 1997. Nutritional analysis was performed at The Ohio

Table 1. Micronutrients Applied to Each Two-Gallon Pot (Mg/Pot) Calculated from Manufacturers' Guaranteed Analyses, or from Compost Analysis. All Slow-Release Products Applied at 2# N/ Cu. Yd.

Treatment Name and Micronutrient Source	Slow-Release Fertilizer	Milligrams per Pot				
		Mn	Fe	Cu	Zn	B
Control (no source)	Osmocote 18-6-12	-	-	-	-	-
Biosolids compost	Osmocote 18-6-12	228	1172	25	135	5
STEP HiMag	Osmocote 18-6-12	210	560	35	70	-
Customblend	Customblend 19-5-8	50	180	10	20	-
Sierra	Sierra 17-6-10	22	90	11	11	4
Osmocote Plus	Osmocote Plus 16-8-12	17	119	12	-	5
High N Plus	High N Plus 22-4-8	17	173	9	9	3
Nutricote Plus	Nutricote Plus 18-6-8	13	42	11	3	4

State University's Research-Extension Analytical Laboratory, Wooster, Ohio. One year after potting (June 1, 1997), shoots from all 144 plants were harvested to measure dry weights as an estimate of growth. All data were analyzed as a randomized complete block with three replications. A protected LSD test was used to compare all means ($p < 0.05$).

Results and Discussion

Growth

None of the treatments improved growth (dry weight data not shown) one year after potting. Control plants, which received no supplemental micronutrient fertilizer, were excellent in quality and color.

Growing Medium Nutrient Concentrations

By the end of the growing season (Table 2, Sept. 12), there were few differences in medium micronutrient concentrations between the control and the treatments receiving the commercial micronutrient fertilizers — both Step Hi-Mag and Customblend had higher Mn in the medium; Customblend also had significantly higher copper levels. The compost-amended medium produced higher levels of Mn, Fe, and Zn than controls for both sampling dates. The compost medium also had higher levels of phosphorus on the first date.

Foliar Micronutrient Concentrations

Plants in the micronutrient treatments did have significantly greater foliar Mn and/or Cu than controls (Table 3); however, control plants had excellent color, quality, and size and were not inferior to any treatment.

Conclusions

Even though plants in some micronutrient treatments had higher levels of micronutrients in the medium or in the foliage, the plants grown without any micronutrient source (controls) were just as big and had just as good color. Since all plants have micronutrient requirements, where did the controls obtain micronutrients? Most likely, the source was the bark in the potting media. Table 4 provides the extractable levels of micronutrients in fresh medium compo-

Table 2. The Growing Medium pH, Phosphorous, and Micronutrient Concentrations (ppm) of Container-Grown *Rhododendron* 'Girard Scarlet' on Sept. 12, 1996, and May 27, 1997 (0.005 M DPTA Extraction). Underlined values indicate that they are significantly greater than controls.

September 12, 1996 Treatment	pH	P	Mn	Fe	Cu	Zn	B
Osmocote 18-6-12	4.5	14.8	2.1	30.2	0.3	4.2	2.3
Osm. + compost	5.6	25.6	14.1	58.5	1.6	28.4	1.4
Osm. + STEP	4.8	18.7	7.6	30.1	1.5	11.1	2.0
Customblend 19-5-8	4.8	12.5	7.6	30.3	2.4	11.5	0.9
Sierra 17-6-10	5.0	10.1	4.3	19.0	0.7	12.3	1.1
Osm. Plus 16-8-12	5.3	13.4	2.0	20.0	1.4	4.2	1.9
High N Plus 22-4-8	4.7	5.9	2.9	28.4	0.4	5.2	0.9
Nutricote Plus 18-6-8	5.2	3.6	2.3	17.8	1.1	4.4	0.9

May 27, 1997 Treatment	pH	P*	Mn	Fe	Cu	Zn	B
Osmocote 18-6-12	4.7	-	5.1	23.5	1.6	11.2	0.1
Osm. + compost	5.1	-	16.9	77.2	1.9	26.8	0.3
Osm. + STEP	4.5	-	4.3	26.3	2.3	10.8	0.1
Customblend 19-5-8	4.6	-	5.4	32.4	6.6	14.9	0.1
Sierra 17-6-10	4.7	-	2.8	13.6	0.9	7.7	0.1
Osm. Plus 16-8-12	4.8	-	2.0	19.5	2.1	5.3	0.3
High N Plus 22-4-8	4.8	-	1.5	33.0	0.8	7.1	0.1
Nutricote Plus 18-6-8	4.8	-	1.4	12.2	1.9	5.2	0.2
Adequate ranges for micronutrients (DPTA Extr.)			5-30	15-40	0.5-1.5	5-30	0.7-2.5

* Did not analyze for P in 1997.

Table 3. Foliar Micronutrient Concentrations (ppm) of *Rhododendron* 'Girard Scarlet' the Year After Potting. Underlined values indicate that they are significantly greater than controls.

Treatment	Mn	Fe	Cu	Zn	B
Osmocote 18-6-12 (control)	46.6	60.4	2.4	44.0	31.8
Osmocote + compost	83.9	60.6	3.0	51.8	28.3
Osmocote + STEP	134.4	64.7	2.5	58.0	30.1
Customblend 19-5-8	134.6	58.3	3.6	53.9	45.7
Sierra 17-6-10	85.3	58.2	3.4	52.5	38.2
Osmocote Plus 16-8-12	52.8	61.6	3.7	47.9	34.8
High N Plus 22-4-8	97.4	64.4	4.0	54.4	40.8
Nutricote Plus 18-6-8	62.0	56.2	5.1	46.1	47.0
Adequate ranges for foliar micronutrients	50-200	35-250	6-25	20-200	6-75

nents and in irrigation water. Comparing the values in Table 4 to the micronutrient adequacy ranges in Table 2 suggests that at least when fresh, both types of bark supply adequate Fe and Mn. Compost may supply adequate amounts of all micronutrients tested, whereas the municipal water used in this experiment appeared to be a negligible source.

While this study demonstrated no growth or plant-quality improvement from any of the micronutrient sources used, the study does not prove that with different plants, different media, and different circumstances, micronutrient supplements may not be important. Furthermore, it is possible that controls may have developed micronutrient deficiencies had they been grown longer than one year. This study and the authors' previous work do suggest that in a one-year crop, the primary value of micronutrient supplements may be as "insurance."

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Table 4 . Micronutrient Concentrations (ppm) in the Irrigation Water and Fresh Potting Medium Components (DPTA Extraction).

	Mn	Fe	Cu	Zn	B
Irrigation water	0.03	0.03	0.06	0.30	0.06
Technagro compost	45.4	37.3	2.2	57.5	1.8
Pine bark	81.4	37.4	0.2	2.2	0.6
Composted hardwood bark	93.1	38.7	0.3	2.7	0.5
Peat	0.2	21.1	< 0.1	0.7	0.1

Effects of Nursery Production Practices on the Growth, Insect Resistance, and Stress Tolerance of 'Sutyzam' Crabapple in the Landscape

John E. Lloyd, Daniel A. Herms, and Mary Ann Rose

Summary

The objective of this study was to determine if fertilization and irrigation practices in the nursery affect plant performance following outplanting in the landscape. Crabapples (*Malus* 'Sutyzam') grown in containers under all combinations of low (irrigated at 50% container capacity) and high moisture (irrigated at 25% container capacity) and three fertilizer concentrations (50, 200, and 350 ppm N) in the nursery in 1997 were outplanted in a low-maintenance landscape in 1998. Tree growth in the landscape was highly correlated with nitrogen content of plants when they left the nursery. High fertility regimes in the nursery resulted in faster growth in the landscape, but only for trees exposed to the low-moisture treatment in the nursery (which decreased nitrogen leaching from containers). However, trees receiving the high fertility regime were also less resistant to insects (eastern tent caterpillar, gypsy moth, and whitemarked tussock moth) and less tolerant of drought stress.

Introduction

Rapid growth of trees in the nursery is necessary to shorten production schedules and maintain profit margins. Furthermore, nutrient loading of plants in the nursery has been proposed as a strategy for increasing growth of transplants in the years following outplanting, the period when nutrient uptake may be limited by root damage and when remobilization of stored nutrients stimulates increased shoot growth (McAlister and Timmer, 1998). However, nurseries are also under increasing pressure to conserve water and limit nutrient runoff. These conflicting management objectives may be resolved through efficient use of water and nutrients if actual plant requirements can be determined. Recent studies have shown that it is possible to decrease fertilizer use in nursery production of containerized plants without sacrificing plant growth (Struve and Rose, 1998; Rose and Wang, *in press).*

Hamilton *et al.* (1981) has suggested that conservative use of fertilizer in nursery production may increase establishment and stress tolerance of plants once they reach the landscape. They argue that lower nutrient concentrations increase root growth relative to shoot growth, resulting in increased stress tolerance. Other studies have shown that reduced fertility regimes can increase insect and disease resistance by decreasing the nutritional value of the plants for microbes and insects and by increasing concentrations of plant defense compounds (Herms and Mattson, 1992).

The objective of this study is to determine how fertilization and irrigation practices in the nursery affect performance of trees fol-

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lowing outplanting in the landscape. Parameters examined in this study include trunk growth, photosynthesis, stomatal conductance, and insect resistance.

Materials and Methods

On April 15, 1997, rooted cuttings of *Malus* 'Sutyzam' (Sugar Tyme™ crabapple) were transplanted to 8.6-liter containers and then exposed to all possible combinations of three fertilizer treatments (50, 200, and 350 ppm N) and two moisture levels for the duration of the growing season. The high-moisture-level treatments were irrigated when container moisture was at 25% container capacity; the low-moisture-level treatments were irrigated at 50% container capacity. The experiment was designed as a randomized complete block, with one replicate of each of the six treatment combinations in each of four blocks (Rose, *in preparation*). The moisture and fertilizer treatments were discontinued in October 1997.

The crabapple trees were moved from Columbus to the Wooster campus of The Ohio State University's Ohio Agricultural Research and Development Center (OARDC) on May 1, 1998, and were transplanted into a turf landscape on May 29, 1998. In order to evaluate the effects of the prior year's nursery treatments, trees were arranged in the same randomized complete block design used in the nursery experiment. A low-maintenance landscape environment was maintained in 1998. Trees were not fertilized and were irrigated only three times — on the day of transplanting, again one week later, and finally on August 4, during a period of drought.

To determine effects of the prior year's nursery treatments on tree physiology, the authors quantified growth, photosynthesis, and stomatal conductance. Effects on growth were determined by measuring trunk diameter (50 cm from the ground) on June 17 and again on October 23. Photosynthesis (μmol m^{-2} s^{-1}) and stomatal conductance (cm s^{-1}) were measured using a Licor 6200 portable photosynthesis system on July 30 and 31 during the drought, and again on September 1, two days after significant rainfall.

Three experiments were conducted to determine effects of fertilizer and irrigation on insect resistance. On May 7, prior to outplanting, experiments were initiated with third instar eastern tent caterpillar *(Malacosoma americanum)* and third instar gypsy moth *(Lymantria dispar)*, both of which are spring-feeding insects. To determine if effects on insect resistance were consistent throughout the field season, a third experiment was initiated on August 25 with first instar whitemarked tussock moth larvae *(Orgyia leucostigma)*, a late-season defoliator. Each of the three experiments was conducted under controlled conditions in the laboratory. Larvae were fed foliage from the experimental trees, and their growth determined by measuring their weight immediately before and after the experiment. Leaves and caterpillars were confined to petri dishes (15 cm in diameter, 2.5 cm high) containing a base of plaster of paris. Water added to the plaster base provided a high-humidity environment, which maintained the turgor of the leaves. Petri dishes were then randomly positioned in a growth chamber maintained at 25°C with an 18:6 day:night photoperiod.

Results and Discussion

Tree Growth

The fertilization regime applied during the previous year in the nursery had a significant effect on tree growth in the landscape. However, the effect of fertilization was dependent on the irrigation regime with which it was combined (Figure 1). When trees were grown under the low-moisture regime in the nursery, growth in the landscape increased at each level of fertilization. In fact, trees that received the high-fertilization rate in combination with the low-moisture treatment in the nursery grew substantially faster in the landscape than trees receiving any other treatment effect.

When trees were exposed to a high level of irrigation in the nursery, the effects of fertilization on subsequent growth in the landscape were not as dramatic. Increasing the rate of N-fertilization in the nursery from 50 to 200 ppm did increase growth following outplanting. However, increasing the rate from 200 to 350 ppm had no additional effect (Figure 1).

The carry-over effect of nursery fertilization on subsequent growth in the landscape is somewhat surprising, since fertilization rate had no effect on tree growth in the nursery, although the irrigation regime had major effects (Rose, *in preparation).* However, these results can be explained if nitrogen accumulated by the tree in the nursery was stored and then used to support growth the following year. Indeed, growth in the landscape in 1998 was highly correlated with nitrogen concentration of the dormant plant following the 1997 growing season (Figure 2).

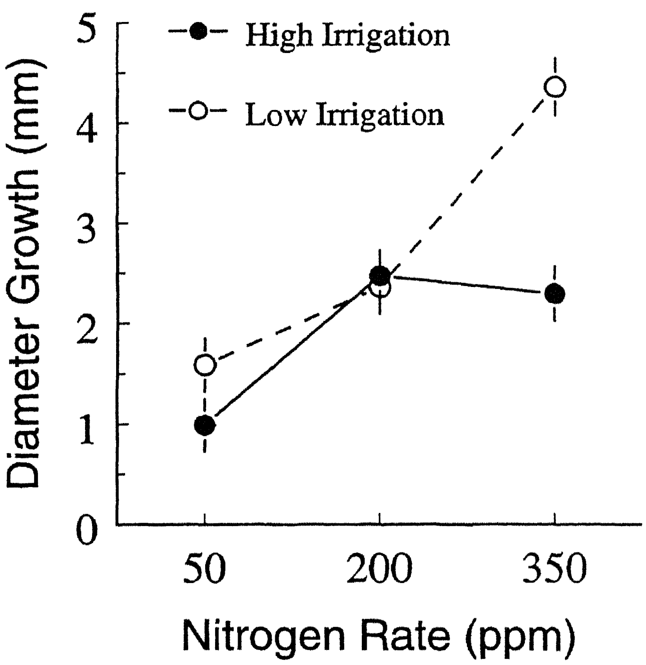

Figure 1. Effect of fertilization and irrigation regime in the nursery in 1997 on trunk diameter growth of *Malus* 'Sutyzam' in the landscape following outplanting in 1998.

The lack of effect of the high-fertilization rate on tree growth when applied in combination with the high-moisture treatment is consistent with the role of stored nitrogen as an important determinant of plant growth the following year. Dormant trees in the low-moisture treatment had a higher concentration of nitrogen (1.95%) than did trees from the high-irrigation treatment (1.74%), because less nitrogen was leached from containers in the low-moisture treatment (Rose, *in preparation).*

Photosynthesis and Stomatal Conductance

As plants experience moderate to severe drought stress, photosynthesis becomes limited by closure of stomata (pores in the leaf through which gas and water vapor enter and exit). Stomatal conductance is a measure of the rate at which water vapor moves from the leaf through the stomata to the atmosphere by means of transpiration. As stomata close and transpiration decreases, stomatal conductance declines. Closure of stomata conserves water by decreasing transpiration, but at the same time decreases uptake of CO_2 from the atmosphere. Not all plants are affected by drought to the same degree. Drought-tolerant plants maintain higher rates of photosynthesis and stomatal conductance during drought than do plants that are less tolerant of drought stress (Schulze, 1986; Kubiske and Abrams, 1993).

In 1998, photosynthesis and stomatal conductance were measured on July 30 and 31 during drought conditions. There had been no rain the previous week, and over the

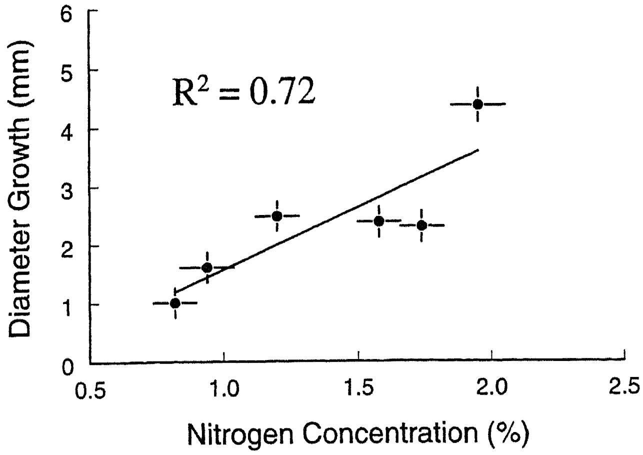

Figure 2. Relationship between whole-plant nitrogen concentration of dormant plants in the nursery in 1997 and subsequent growth in the landscape following outplanting in 1998.

previous three weeks evaporation exceeded precipitation by 3.88 inches. Photosynthesis and stomatal conductance were also measured on September 1, following the end of the drought (4.36 inches of precipitation fell between August 23 and 29).

The fertilizer regime used in the nursery had clear effects on drought stress tolerance following outplanting. Plants grown under the low-nitrogen treatment (50 ppm) were more tolerant of drought than plants grown under the two higher nitrogen levels. This is indicated by the higher photosynthesis and stomatal conductance rates that low-N plants were able to maintain during drought (Table 1). Trees receiving the two higher fertilization rates had significantly lower rates of photosynthesis and stomatal conductance during the drought period. On September 1, after drought conditions had abated, the photosynthesis and stomatal conductance rates of all trees increased dramatically, and treatment effects disappeared (Table 1).

There are a number of reasons why high rates of N-fertilization may decrease drought stress tolerance. Increased nitrogen availability generally stimulates shoot growth to a greater degree than root growth, thus decreasing the root:shoot ratio of the tree (Linder and Rook, 1984). In this way, fertilization can simultaneously increase tree water demands while decreasing the tree's ability to acquire water during drought. Trees receiving the low-fertilizer treatment in this experiment had a higher root:shoot ratio when they left the nursery (Rose, *in preparation*), which could have been responsible for their increased tolerance of drought stress.

Table 1. Effect of Fertilizer Regime Used in the Nursery in 1997 on Net Rate of Photosynthesis (μmol m^{-2} s^{-1}) and Stomatal Conductance (cm s^{-1}) of *Malus* 'Sutyzam' in the Landscape Following Outplanting in 1998 (mean ± standard error). Means Within a Column Followed by the Same Letter Are Not Significantly Different.

	July 30		July 31		September 1	
Nitrogen Fertilization Rate (ppm)	Photosynthesis Rate	Stomatal Conductance	Photosynthesis Rate	Stomatal Conductance	Photosynthesis Rate	Stomatal Conductance
50	4.3 ± 0.5 a	0.05 ± 0.01 a	4.3 ± 0.5 a	0.06 ± 0.01 a	10.5 ± 0.6 a	0.32 ± 0.02 a
200	3.4 ± 0.5 ab	0.04 ± 0.01 ab	2.5 ± 0.5 b	0.03 ± 0.01 b	12.3 ± 0.6 a	0.32 ± 0.02 a
350	2.4 ± 0.5 b	0.03 ± 0.01 b	2.1 ± 0.6 b	0.03 ± 0.01 b	11.6 ± 0.6 a	0.26 ± 0.02 b

High rates of fertilizer may also decrease drought stress through effects on the chemical composition of leaves. A well-documented effect of high fertilization rates is to decrease foliar concentration of tannins and other secondary metabolites that provide trees with stress tolerance and insect resistance (Herms and Mattson, 1992). Tannins impregnate the outer wall of epidermal cells, making them more impervious to water, and thus contribute to water conservation under stress (Bussotti *et al.*, 1998). Analysis of foliar tannin concentrations of these trees is under way.

Insect Resistance

Numerous studies provide strong evidence that fertilization almost always decreases resistance of trees to defoliating insects. This is because fertilization generally increases the nutritional value of the plant and decreases concentrations of the trees' defensive chemicals (Herms and Mattson, 1997). The results of this study are consistent with this pattern. As the fertilizer rate used in the nursery increased, so did the insect growth rate (Figure 3). This was true for both early-season (gypsy moth and eastern tent caterpillar) and late-season (white-marked tussock moth) species. Only eastern tent caterpillar was affected by the irrigation regime used in the nursery. Larvae grew faster on plants receiving the high-moisture treatment.

Conclusions

The fertilization regime used in the nursery during 1997 had major effects on the growth, stress tolerance, and insect resistance of crabapple in a low-maintenance landscape in 1998, even though it had little effect on tree growth in the nursery. Conversely, the irrigation regime used in the nursery had little effect on trees following outplanting, although it had major effects on tree growth in the nursery.

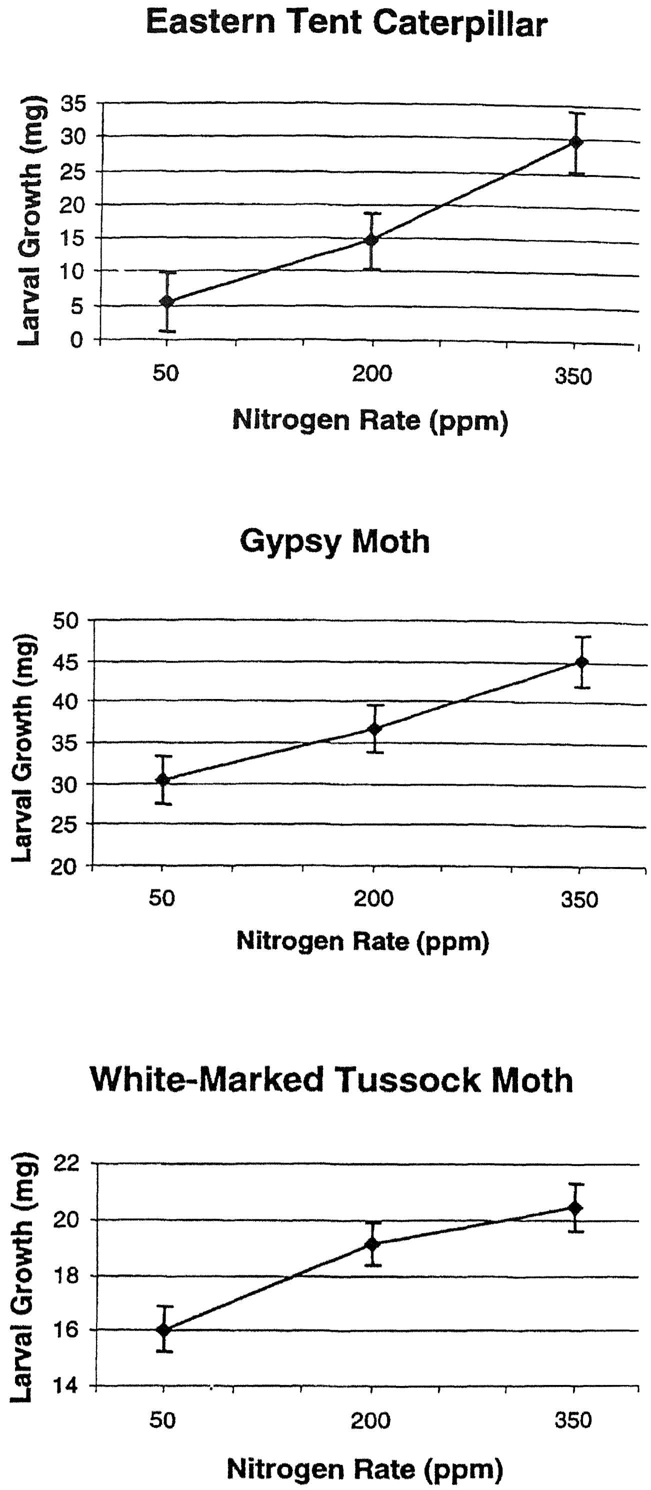

Figure 3. Effect of fertilization regime in the nursery in 1997 on growth of eastern tent caterpillar, gypsy moth, and whitemarked tussock moth larvae feeding on *Malus* 'Sutyzam' in 1998.

The growth rate of trees in the landscape was highly correlated with their nitrogen concentration when they left the nursery. The higher the nitrogen content of the plant, the faster it grew following outplanting. However, increased fertilizer rates in the nursery also decreased the drought stress tolerance and insect resistance of trees once they were in the landscape, possibly because they had lower root:shoot ratios and decreased concentrations of naturally occurring defensive chemicals. Trees receiving the high-fertilizer rate in the nursery had lower rates of photosynthesis during drought, although there were no differences when soil moisture was favorable. Growth rates of eastern tent caterpillar, gypsy moth, and whitemarked tussock moth all increased as the rate of fertilizer increased.

Nutrient-loading in the nursery has been proposed as a strategy for increasing growth and hastening establishment of trees following transplanting (McAlister and Timmer, 1998) and thus could represent a value-added component of nursery production. This is especially true in situations where fertilization is undesirable, such as in forest regeneration where fertilization favors competing vegetation. However, this study suggests that nutrient-loading may be most beneficial when trees are growing under favorable conditions and may be detrimental under stressful conditions. With the exception of a moderate drought from mid-July to early August, growing conditions for trees were good in Wooster in 1998, and there was little insect pressure in the experimental plots. The decreased stress tolerance and insect resistance of trees heavily fertilized in the nursery may counteract positive effects of nutrient-loading during years of more severe drought and insect outbreaks sometimes experienced in low-maintenance landscapes.

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Floral Development and Potential for Interspecific Hybridization of *Aesculus parviflora* and *Aesculus pavia*

Ann Chanon and Pablo Jourdan

Summary

Interspecific hybrids among *Aesculus* species, where possible, offer opportunities for improvement of a variety of horticultural attributes for key members of this genus. The authors have begun a program to develop such hybrids, focusing on *A. parviflora*, the bottlebrush buckeye, and *A. pavia*, the red buckeye. Preliminary findings on the floral biology and fruit set in *A. parviflora* are reported here. The results indicate that crosses with *A. parviflora* as the pistillate parent may be difficult, although possible.

Introduction

Aesculus parviflora, the bottlebush buckeye, was first described in 1788 by Walter. It is native to South Carolina, Georgia, and northern Florida in populations that are isolated from one another (Harden, 1957). These native populations are most often found in association with rivers where the seeds are dispersed by water (Wyatt, 1985).

Despite its southern origin, this shrubby, stoloniferous plant is hardy to Zone 4. It ranges in height from 8–15 ft. and blooms for two to three weeks in mid- to late summer (Clark, 1982). White flowers are borne on panicles 8–18" in length. Flowers are either staminate or perfect, and both produce long slender filaments that extend from the flower, giving the panicles the 'bottle brush' appearance.

Aesculus parviflora is an excellent landscape plant; it does well in a sunny or a shaded location and can tolerate either alkaline or acid soil. The leaves unfurl in early spring, and they maintain healthy, dark-green foliage throughout the year. It does not suffer from the many foliage problems (e.g., scorch) associated with other *Aesculus* species (Dirr, 1990).

The plants have only moderate to poor seed set, and the reasons for this are uncertain. Such low seed set hampers efficient propagation of the plant in the trade. Much research to date has focused on the difficulties of asexual propagation from shoots and stolons (Fordham, 1987).

Aesculus pavia L., the red buckeye, is also native to the southeastern United States. It was the first of the North American *Aesculus* species to be described by Plukenet in 1696 (Taylor, 1982). Within *Aesculus*, four members are recognized in the section *Pavia: A. flava, A. glabra, A. pavia*, and *A. sylvatica*. These species grow in close proximity and have overlapping ranges.

Natural interspecific hybrids of *A. pavia* are quite common within this section, and flower color is only one of the traits affected (Taylor, 1982). In addition, hybrids between *A. pavia* and *A. hippocastanum*, a member of

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a different section, are known and have been named *A.* x *carnea* (Upcott, 1936).

A. pavia is a large shrub to small tree, depending on pruning, and is hardy to Zone 4. It ranges in height from 10–25 ft. and about the same in spread. Panicles bloom in May and range in size from three to eight inches; flowers can range from yellow to a dull red to a bright crimson, depending on the specimen.

The plant is relatively rare in cultivation, which may be due in part to variability in flower quality and to a fairly slow growth rate. Red buckeye is best propagated by seed, but grafting is possible. Seeds gathered in early fall should be planted immediately since they deteriorate with storage (Dirr and Heuser, 1987).

Harden (1957) noted that *Aesculus* species hybridize easily, but no natural hybrids between bottlebrush and other buckeyes have been observed. All *Aesculus* share the same number of chromosomes $2n = 20$ with the exception of *A.* x *carnea*, which is polyploid with $2n = 40$ (Hoar, 1927). It is unclear whether this lack of interspecific hybrids with bottlebrush buckeye is the result of incompatibility barriers or just due to the separation in bloom time, since most *Aesculus* flower in early spring, but the bottlebrush does so in summer. Some attempts have been made to produce artificial hybrids between *A. parviflora* and other *Aesculus*, but these have not yet been successful (R. Marquard, personal communication).

This research is examining the barriers that so far seem to prevent the formation of hyrids between *A. pavia* and *A. parviflora*. To this end, this study is examining in some detail the floral biology of these species, focusing first on *A. parviflora*, looking at inflorescence structure, pollen longevity, and seed set after controlled intra- and inter-specific pollination. Some preliminary findings are reported here.

Materials and Methods

Fresh pollen was collected from nine different *A. pavia* trees, four from the Dawes Arboretum, two from The Ohio State University's Columbus campus, two from the Holden Arboretum, and one from a private residence in Lake County. Pollen was collected by rubbing freshly dehisced anthers across a nylon screen onto a collecting dish. Between 25 and 50 mg of pollen were placed into size 00 gelatin capsules and stored over a drying agent in a -20°C freezer.

Pollen viability was assessed prior to use for hand pollination and was estimated using an *in vitro* pollen germination method. A sample of pollen was taken from the freezer, equilibrated at room temperature, and applied to the germination medium. The medium contained 10% (w/v) sucrose and was made following the Brewbaker and Kwack (1963) procedure. The plates were incubated upside down for 24 hours.

Following incubation, a drop of cotton blue stain was placed on the areas where the pollen had been applied and covered with a cover slip. A pollen grain was counted as germinated if the pollen tube was at least twice the diameter of the pollen grain.

Panicles on *A. parviflora* became visible after bud expansion and were observed weekly until flowering began. Panicles were tagged, and the number of staminate flowers removed was recorded daily. The complete flowers were emasculated when the buds were approximately six millimeters in length, and the anthers were just visible. The panicles were then covered with pollination bags to exclude insects and other sources of contamination.

When the styles reached approximately 1 cm in length, pollinations began. Flowers were either pollinated once or pollinated daily until the stigmas turned black. Each day, fresh pollen was taken to the field where it was allowed to warm up prior to application. The stigmas were coated with pollen by moving the stigma up and down the side of the gel cap until the entire surface was covered. Fruit set was assumed to have occurred if the ovary swelled and turned from white to green. About 10 weeks following pollination, the fruits were harvested.

Results and Discussion

Flower Gender

Panicles were observed from a number of individual plants at locations in and around Columbus as well as the Holden Arboretum. Of the 400 panicles observed, the average number of flowers per panicle was 319. On average, 43% of those panicles produced no complete flowers. Those panicles that had complete flowers produced an average of eight complete flowers per panicle but had a range that was from one to 74 complete flowers. The complete flowers occurred in all parts of the panicle and were most often found in the upper-most third of the panicle. This was unlike other species of *Aesculus*, where most of the complete flowers are located at the base of the panicle (Harden, 1956).

Pollen Viability

Pollen from the six *A. pavia*, the *A.* x *carnea*, and two *A. parviflora* sources was germinated on artificial medium to evaluate their viability as pollen sources. Both *A. parviflora* samples germinated at greater than 90% efficiency. The *A.* x *carnea* sample germinated at approximately 50% efficiency. Germination for the various *A. pavia* pollen samples germinated in a range from 56–77%. All of the pollen sources were judged fit for use in the pollination experiments.

Pollinations

Five *A. parviflora* plants were used for the pollination experiments. Two of those plants produced very little to no seed, but this may have been the result of the 1998 summer drought conditions. At 10 weeks post-pollination, fruits were harvested, and the percent of fruit set was calculated (Table 1).

Fruit set was affected by the pollen source. The unpollinated controls set no fruit, which suggests that pollination is required for fruit development and that parthenocarpy and apomixis were unlikely. This agrees with previous research by Hardin (1955), where no parthenocarpy and apomixis had been reported. In addition, the absence of fruit in such plants suggests the risk of pollen contamination may be low, and accidental pollinations would be rare.

Pollinations using *A. pavia* pollen produced, on average, 7.3% fruit set, but the range was wide, from a low of 2.3% to a high of 26.1% fruit set depending on the *A. pavia* individual (genotype).

Pollinations with *A.* x *carnea* pollen resulted in only a 1.5% fruit set; whether this low set is the result of differences in chromosome numbers or just low pollen fertility is not clear at this time. The intraspecific pollination (among different *A. parviflora* individuals) had a fruit set of 21.2%.

Self pollinations (within the same plant) had a 25.0% fruit set, suggesting perhaps that self-incompatibility is not a problem in this species; however, additional tests are needed before firm conclusions can be made. Both of these controlled pollinations resulted in higher fruit set than the 13.5% observed from open pollinated flowers (bulked pollen from multiple *A. parviflora* sources). These results indicate:

- Fruit set seems to occur only at one-fourth of the potential (i.e., bisexual flowers) for the plant.
- Despite the low frequency of complete (or bisexual) flowers per panicle and the overall low percentage of fruit set, it remains feasible to attempt interspecific

Table 1. Pollination and Fruit Set on *Aesculus parviflora* Using Various Pollen Sources and Pollination Methods.

Pollen Source	Number of Pollinations	Number of Fruit Set	Relative Percent Fruit Set
Unpollinated	150	0	0.0
Interspecific Pollinations			
A. x *carnea*	275	4	1.5
A. pavia	951	69	7.3
Intraspecific Pollinations			
*A. parviflora**	353	75	21.2
Self pollination	144	36	25.0
Open pollination	230	31	13.5

* Combined data of multiple paired pollinations.

hybridization as the fruit set after such crosses approached that of intraspecific crosses.

Further work is needed to optimize the interspecific hybridization system for *A. parviflora* and *A. pavia*. Factors to be considered include:

- The optimum storage conditions for pollen preservation to enhance these out-of-season pollinations;
- The confirmation that plants resulting from controlled intraspecific pollinations are indeed hybrids;
- The increased attempt at reciprocal crosses;
- The broadening of the genotype pools for pollination by using multiple sources of plants;
- The more detailed, microscopic study of the fate of pollen on the pistil to determine fertilization and embryo development.

Acknowledgements

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Environmental and Cultural Problems of Ornamental Plants in Ohio: 1998

Pamela J. Bennett and Jane C. Martin

Summary

The winter of 1998 in Ohio was milder than normal due to El Niño. Temperatures were above average, and precipitation typically fell as rain rather than snow. Reports of winter-injured plants were essentially nonexistent, and marginally hardy plants that are normally killed to the ground in winter (Buddleia, some hydrangeas, and more) were not damaged this winter. Spring was fairly typical across Ohio except for a wetter than normal April and June.

August and September were drier than normal in many parts of the state, and September was warmer than normal. This caused lawns to go dormant and trees and shrubs to show early signs of stress, such as wilting, early fall coloration, leaf scorch, and leaf drop.

Introduction

This report includes a compilation of Ohio weather conditions and noteworthy environmentally induced and cultural plant problems in 1998. Observations were drawn from information provided in Ohio State University Extension's *Buckeye Yard and Garden Line,* the Ohio Department of Natural Resources *Monthly Water Inventory Report,* and information from the State Climatologist's Office for Ohio.

Discussion

Weather Background

January and February in Ohio were warmer than normal. For example, temperatures in Columbus averaged 11.1°F above normal in January and 10.8°F above normal in February, while Cincinnati averaged 10.5°F above normal in January and 8.7°F above normal in February. During the January through March period, precipitation in Ohio fell as rain with little snowfall, due to the warmer than normal temperatures. Northeastern Ohio was the only part of the state that experienced near normal snowfall.

Temperatures in March and April were nearly normal, except for a few days of highs in the low 80s at the end of March. A few plants broke bud early and were later injured by low temperatures. Rainfall in April was above normal across Ohio, by an average of approximately 2.0". It was the seventh wettest April in Ohio in 116 years.

May brought above-normal temperatures across the state — on average for the month, Cleveland was above normal by 6.4°F; Columbus above normal by 6.1°F; and Cincinnati was 3.7°F above normal. Rainfall was above normal in the southern half of the state and below normal in the northern half.

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Rainfall varied widely across Ohio with typical summer-like patterns of showers, heavy storms, high winds, and hail. The northern one-third of the state was very dry the last three weeks in May.

Temperatures in June were normal, though Columbus was slightly above average in June by 2.4°F. June was noticeably wet, and the rainfall average was 3.2" above normal, the second wettest June in 116 years. Rainfall occurred as light showers and intense downpours as part of dangerous storms and thunderstorms with several tornadoes reported. Floods occurred in the east-central and southeastern parts of the state. Precipitation for the first half of the 1998 calender year was above normal throughout the state, with the average being 5.0" above normal.

Temperatures in July were normal across the state. Rainfall for July was below normal for most of the state, averaging 87% of normal, or -0.5".

August temperatures were slightly above normal. Rainfall was above normal in the northern half of Ohio, but well below normal in the southern half. Monthly totals varied greatly across the state, from a low of 0.4" for the month in Westerville (Franklin County) to a high of 14.9" in Fostoria (Hancock County). Despite dry weather from mid August into early September, yearly rainfall totals (through September) were still above normal in several locations. Cincinnati was 11.0" above normal for the year, and the Wooster area was above normal by 5.5". Even though Columbus reported only 50% of normal rainfall for the July–September period, the area was at normal yearly rainfall totals.

September was warmer than normal and drier than normal across most of the state. Cleveland recorded average September temperatures as +3.1°F, Columbus was +6.1°F, and Cincinnati was +4.3°F. Rainfall was noticeably below normal. The state average was 1.3", which was 1.7" below normal for the month. This was the seventh driest September in the past 116 years.

Despite below-normal rainfall across Ohio in the late summer-early fall, precipitation for the 1998 calendar year was above normal at the end of September; the state average was 3.5" above normal. Lawns remained dormant in many areas, and deciduous trees and shrubs continued to wilt, scorch, and drop leaves earlier than usual.

Cultural Problems

Ohioans enjoyed a bounty of blooms in the spring despite a mid-March freeze. Crabapples at the Ohio Agricultural Research and Development Center's Secrest Arboretum in Wooster and other plants statewide bloomed about 10 days to two weeks earlier than the previous year. This phenomenon occurred throughout the spring and summer bloom period; sometimes blooming was noted two-and-one-half to three weeks earlier than occurred in 1997.

Pachysandra

Several reports of a problem on pachysandra occurred early in the spring. Plants exhibited a marginal scorch symptom that in some cases encompassed a third to a half of the leaf. There were no symptoms of Volutella leaf and stem canker; it was thought to be related to winter dessication.

Turf

In most locations in Ohio, turf quality was poor by late June. Turf had gone from beautiful, lush, and green to ugly, stressed, and yellow-brown. Despite the fact that soil in many areas of the state was saturated, turfgrass showed heat stress quickly by late June. Roots had suffered in saturated soils in spring, fertilizers had worn off, and some turfgrasses experienced heavy seedhead formation; all of these factors contributed to poor quality. Also, from early August to mid September, dry conditions in many areas of the state led to lawns becoming dormant.

Yellowing of Birch and Other Trees

Numerous reports concerned a problem with river birches. In mid-summer, leaves yellowed and fell from the trees. Speculation was that the problem was not related to any disease, but to hot and dry weather that hit most parts of the state.

In dry weather, trees may lose up to 10% of the foliage to reduce water loss into the air; this amount of loss is not considered harmful to the plant. Also, inner leaves may be shaded out and are lost for lack of sunlight. Watering may serve to reduce stress but will not aid in recovery during the summer. If trees are fairly healthy, they will leaf out normally the following spring.

Numerous plants exhibited leaf yellowing and some leaf drop, especially of inner foliage, during the hot, dry spell in August. Plants experiencing this, in addition to the birches, were poplars, tuliptree, katsuratree, sweetgum, and many others. Early fall coloration was also evident on stressed burningbush and sourwood.

Horticulture Information

Heat Zones New This Spring

In the fall of 1997, a Plant Heat-Zone Map was released by the American Horticultural Society (AHS). The map was developed with the leadership of Dr. Marc Cathey. The heat zones are based on the average number of days per year that temperatures rise above 86°F. Eighty-six degrees was chosen because cellular proteins are damaged at temperatures above this.

The United States is divided into 12 zones. By using both rating systems, the AHS heat zones and the USDA hardiness zones, gardeners can select plants that are adapted to heat as well as cold.

Approximately 1,200 plants will be rated and eventually plant tags will have four numbers on them that indicate:

1. The coldest hardiness zone in which the plant will thrive.
2. The warmest hardiness zone in which the plant will thrive.
3. The warmest heat zone in which the plant will thrive.
4. The coolest heat zone in which the plant will thrive.

Root Questions

Despite recent research that has provided a greater understanding of tree root morphology, misconceptions remain and are being passed on to the public. In 1998, *BYGL* participants frequently discussed client questions concerning root problems and the confusion over the subject. The following information was provided in *BYGL* 98-23:

"Tree root systems resemble broad, shallow discs rather than tight, deep spheres. According to work done by Nina Bassuk (Cornell University), most of the root system is in the upper three feet of the soil, and about 80% of the feeder roots are in the upper six to eight inches of the soil. Also, more roots are found outside rather than inside the drip line. Many reasons have been given for this shape, but one of the most uncomplicated explanations has to do with oxygen. Tree root cells must absorb oxygen from the environment (the soil) since trees lack a cardiovascular system (heart, lungs, etc.) to pump oxygen to the roots. Put simply: deep soil = less oxygen = few roots; shallow soil = more oxygen = more roots.

"Statements that imply root growth is influenced by trees 'seeking' water, nutrients, or other resources falsely imply that trees can 'sense' such things — as though they have a nervous system. The rate and direction of root growth is not influenced by a sentient ability for roots to pursue, search, or hunt for resources. Root growth is primarily controlled by the individual cells at the tips of the roots. If those cells acquire adequate resources from their surrounding environment (e.g., oxygen, water, nitrogen, etc.), they will grow. If resources are inadequate or conditions harsh, they will not grow. Root growth may follow a gradient, from a low concentration of resources to a high concentration, and this observation may insinuate that roots are 'seeking' those resources; however, it remains a simple matter of available resources: roots will grow where roots can grow."

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1. The Ohio Department of Natural Resources *Monthly Water Inventory Report* is available at:

   http://www.dnr.state.oh.us/odnr/water/pubs/newsltrs/mwirmain.html

2. Dr. Jeffrey Rogers, State Climatologist, with the State Climatologist's Office for Ohio, provides current and archived weather information for several locations in the state. This information is available at:

   http://asp1.sbs.ohio-state.edu/climoff.htm

Insect and Mite Activity Noted in Ohio Nurseries and Landscapes: 1998

Joseph F. Boggs, David J. Shetlar, Jane C. Martin, Pamela J. Bennett, James A. Chatfield, and Gary Y. Gao

Summary

Damaging infestations of mimosa webworm *(Hyphantria cunea)* and the common bagworm *(Thyridopteryx ephemeraeformis)* occurred this season in various areas of Ohio, with bagworm populations being primarily concentrated in southern and central Ohio. Sawfly populations remained low throughout much of the state with the exception of dogwood sawfly *(Macremphytus tarsatus)*, redheaded pine sawfly *(Neodiprion lecontei)*, and the scarlet oak sawfly *(Caliroa quercuscoccineae)*. Heavy infestations of locust leafminer *(Odontota dorsalis)* caused very noticable damage to black locust, particularly in the southern part of Ohio, and lilac leaf miner *(Gracillaria syringella)* produced damage to Japanese tree lilacs in southeastern Ohio. Adults of several species of conifer bark beetles emerged at the same time that some areas of the state were experiencing severe moisture deficits, fueling speculation that dry conditions could have made conifers more susceptible to attack. Numerous species of eriophyid mites were observed this season, but various rust mites and a 'rosette mite' *(Trisetacus gemmavitians)*, caused the greatest concern. Japanese beetle *(Popillia japonica)* adults were present for an extended period of time; however, most late fall larvae had reached the normal third instar overwintering stage. Bluegrass billbug *(Sphenophorus parvulus)* and chinch bug *(Blissus leucopterus)* populations were high this season, especially in southern and central Ohio.

Introduction

Insect and mite activities reported in 1998 in Ohio State University Extension's *Buckeye Yard and Garden Line (BYGL)* and *Pest Evaluation and Suppression Techniques (PEST)* newsletters as well as other sources are summarized and compared to previous seasons. Unusual insect and mite activity is also reported.

Discussion

Nest-Making Caterpillars and Bagworms

Despite its common name, fall webworms *(Hyphantria cunea)* generally appear in Ohio sometime in early July. However, this season, the first generation made an unusually early arrival with eggs hatching in northeastern Ohio in mid-June. There are two generations in Ohio, but eggs typically

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hatch over an extended period of time, producing considerable generational overlap. Larvae of both generations cause the same damage, by feeding on leaves shrouded in webbing, but unless limited by disease and/or beneficial insects, the nests produced by the second generation are generally more numerous and conspicuous compared to those produced by the first generation.

High populations occurred in localized areas throughout much of Ohio; however, beneficial insects appear to have had an impact on some of those populations. In 1997, Dan Herms (Ohio State University Department of Entomology) reported heavy infestations near Wooster, Ohio, but larvae randomly collected from those populations were heavily parasitized (5). This season, Herms noted that webworm populations were greatly reduced in those same geographical areas.

The unsightly nests of mimosa webworm *(Homadaula anisocentra)* were again on prominent display on honeylocust in Ohio this season; however, unlike last year, populations seemed more evenly distributed throughout the state rather than being concentrated mostly in southern Ohio (5). Larvae of this moth skeletonize the lower leaf surface as they feed within 'nests' consisting of webs spun over the foliage. Normally, two to three generations occur in Ohio, with each generation overlapping so that larvae are present at all times. This occurs because females lay eggs in the nests produced by the previous generation.

Female mimosa webworm moths were first observed in northeastern Ohio in late May, and the resulting first-generation nests were abundant and very noticeable by mid-to-late June throughout Ohio. First instar larvae of the second generation were found in nests in early August. Last season, a distinct third generation was noted because of an unusual break in activity that lasted from mid-August to early September (5). This year, no such pause was observed, and although a third generation occurred, it was not easily discernable from the second generation.

Two unusual nest-making caterpillars made their debut this season in the pages of *BYGL*. Both the ailanthus webworm *(Atteva punctella)* and the redbud leaffolder *(Fascista cercerisella)* were observed late in the season causing damage to their respective namesakes in southwestern Ohio. The redbud leaffolder is so named because the larvae typically create nests by folding over leaf edges. They may also 'stick' two leaves together. Thick bundles of silk arranged along the leaf edges give the appearance that the leaves or folds are stitched together. The larvae feed within these nests as skeletonizers and consume the epidermis of both the upper and lower leaf surfaces. The caterpillars have reddish-brown head capsules and alternating black and light green bands running the length of their body. They pupate to become a medium-sized velvety-black moth.

Ailanthus webworms are the immature stage of an ermine moth. The larvae produce nests on the tree of heaven *(Ailanthus altissima)* by pulling two to three leaflets around a network of loose webbing. The larvae then consume the leaflets. The caterpillars have a wide, light greenish-brown stripe down their backs and several thin, alternating white and olive-green stripes along their sides. They are sparsely covered with short, erect hairs, which help to suspend the caterpillars within the webbing. When disturbed, the caterpillars move backwards out of the nest and drop towards the ground on a strand of silk. Several larvae may be found per nest. Although ailanthus webworms are capable of defoliating their odoriferous namesake, such damage is rare, and the insect is usually of little consequence.

The common bagworm, *Thyridopteryx ephemeraeformis*, once again developed damaging populations in many areas of

Ohio this season. This insect has been on the rise each year in Ohio since the severe winter of 1993–1994 significantly reduced its occurrence (3). As was observed last year, the distribution of this bagworm remains highly variable between the northern and southern parts of the state, with the southern portion tending to have higher populations (5). One difference between the 1997 and 1998 season was that a greater number of damage reports involved deciduous trees. These observations were a reminder that the insect has a wide host range and has been found feeding on more than 128 different species of plants.

The grass bagworm, *Eurukuttarus confederata,* was very evident in southern and central Ohio this season. As its common name implies, this bagworm feeds exclusively on grasses and constructs its bag from parallel bundles of its host plant. Bags produced by early instars are green but later become brown as the grass stems and blades attached to the bag become dry. This turf-dwelling caterpillar emerges and completes its development much sooner than its arboreal cousin, and this may cause some confusion with identification. When the relatively small bags produced by this bagworm begin to appear on vertical surfaces rising above the ground (e.g., tree trunks, fence posts, and more) in mid- to late June, landscapers may incorrectly conclude that they are seeing a second generation of the common bagworm. Of course, both bagworms only have a single generation each year. Unlike the common bagworm, the grass bagworm causes little damage, and infestations seldom warrant control efforts.

Other Caterpillars

In past years, gregarious feeding caterpillars such as the yellownecked caterpillar *(Datana ministra)*, walnut caterpillar *(D. integerrima)*, and the hickory tussock moth *(Lophocampa caryae)* were common, and some sporadic outbreaks were observed (1, 3, 4). However, this season, these caterpillars were conspicuous because of their relative absence from the landscaping.

Conversely, large solitary-feeding caterpillars, such as the four- to six-inch-long hickory horned devil (regal or royal walnut moth, *Citheronia regalis)*, the tomato hornworm (five-spotted hawk moth, *Manduca quinquemaculata)*, and the parsleyworm (black swallowtail butterfly, *Popilio polyxenes)*, were once again a common sight. The catalpa hornworm (catalpa Sphinx moth, *Ceratomia catalpae)* was particularly noticeable, with high populations being reported throughout Ohio. Natural control agents for this insect were also very evident. For example, the white, oblong cocoons of one of the parasitic wasps responsible for reducing populations of this insect were observed 'blossoming' from second generation horned worms in late August in Wooster, Ohio.

Large numbers of white cocoons played a role in disclosing high populations of oak skeletonizer *(Bucculatrix ainsliella)* in northeastern Ohio. In late June, the yellowish-green larvae of the first generation of this moth began pupating. When these caterpillars are ready to pupate, they drop down on silken threads and attach their white, longitudinally ridged cocoons to just about any surface found in the landscape.

Despite their diminutive size, thousands of these cocoons plastered on lawn chairs, plants, screens, houses, napping gardeners, and other surfaces, may be a real nuisance, and there are two to three generations per year. Although early instars feed as leaf miners and later instars feed on the lower leaf surface as skeletonizers, larval-feeding activity seldom causes significant injury. Spray applications are generally not recommended, since the pesticides may kill parasitic wasps that target the cocoons and reduce caterpillar populations.

Sawfly Defoliators

A number of sawfly defoliators caused considerable localized damage this season. These included: dogwood sawfly *(Macremphytus tarsatus)*, redheaded pine sawfly *(Neodiprion lecontei)*, and the scarlet oak sawfly *(Caliroa quercuscoccineae)*. Dogwood sawfly caused damage to native gray dogwood, and the redheaded pine sawfly produced serious defoliation of Scotch pines in several Christmas tree plantations, primarily in southwestern Ohio.

The slug-like, black to dark-green scarlet oak sawfly caused heavy damage to pin oaks in southeastern Ohio. The larvae feed gregariously and skeletonize the lower leaf surface, leaving behind the upper epidermis. Adults damage leaves by inserting their saw-like ovipositor into the upper leaf surface and cutting rows of small pockets for eggs along major leaf veins. There are two to three generations per year. This insect feeds on pin oak and occasionally eastern black oak as well as its namesake, scarlet oak.

Several sawflies with malevolent reputations, based on past histories of causing damage in Ohio, had relatively low populations this season (1, 2, 3). These defoliators included: the early season European pine sawfly *(N. sertifier)*, introduced pine sawfly *(Diprion similis)*, azalea sawfly *(Amauronematus azaleae)*, dusky birch sawfly *(Croesus latitarsus)*, mountain-ash sawfly *(Pristiphora geniculata)*, and the late-season white pine sawfly *(N. pinetum)*. Little widespread damage caused by these sawflies was observed this season.

Leaf Miners

Adults of three leaf-mining sawflies in the genus *Fenusa* were on the wing in northeastern Ohio in late April. These included: birch leaf miner *(F. pusilla)*; elm leaf miner *(F. ulmi)*; and European alder leaf miner *(F. dohrnii)*. At the same time, larval mining activity of the hawthorn leaf-mining sawfly *(Profenusa canadensis)* commenced in southwestern Ohio.

Larvae of these sawflies mine the leaf parenchyma, producing large blister-like, reddish-brown "blotch" mines, which usually extend from the leaf margin toward the midvein. In previous years, all four of these insects caused substantial injury to their hosts in various areas in Ohio. For example, in southwestern Ohio in 1997, the elm leaf miner produced heavy localized defoliation (5). However, with the exception of some heavy, highly localized infestations of hawthorn leaf miner, populations of these insects were relatively low this year.

The annual ravaging of black locust leaves by locust leaf miner *(Odontota dorsalis)* occurred this season throughout much of Ohio (3,5). The digitate blotch mines produced by the larvae coupled with the skeletonized leaves produced by the adult beetles caused many trees to become completely brown by late summer.

The lilac leaf-miner *(Gracillaria syringella)* caused considerable damage to Japanese tree lilacs in southeastern Ohio. Early instar larvae of this tiny moth feed gregariously in blotch-like mines. Leaf-mining activity typically causes the leaves to pucker or curl along the edge of the mines and may cause leaves to drop. Mined portions of attached leaves eventually dry up and become unsightly. Later instar larvae abandon the mines and roll or web together several leaves on which they feed. There are two generations per year, and they may also infest black ash, privet, and euonymus.

Borers

There are numerous species of conifer bark beetles in Ohio. All are in the family, *Scolytidae*, and most belong to one of two genera, either *Dendroctonus* or *Ips*. These beetles burrow into the bark, lay eggs, and the larvae tunnel in and feed on phloem tissue. Their activity produces characteristic 'shotholes' in the bark, making an infested tree look as though it has been peppered with shotgun pellets. Although conifer bark beetles are serious primary pests in many parts of the United States, the species found in Ohio are generally secondary pests, meaning that they prefer to colonize stressed trees.

Weakened conifers cannot defend themselves, because they lack the ability to produce enough sap or gum to "pitch-out" borers trying to enter through the bark. Generally, when trees are under attack by bark beetles, it means they are in serious trouble, usually because of an accumulation of stress-inducing factors (e.g., root decline, moisture stress, and more). Several conifer bark-beetle species emerged in late July in many areas of Ohio. At the same time, many areas of Ohio were in the early stages of a serious moisture deficit. *BYGL*ers speculated that the dry conditions may have predisposed some conifers to attack by the opportunistic bark beetles. Given that colonized trees were most likely already in a state of serious decline, it was noted that trees riddled with conifer-bark-beetle holes cannot be 'saved' using an insecticide approach. The proper treatment for such infested trees is 'basal pruning' (removal).

Adult-emergence dates for several clear-winged moth borers were reported for northeastern Ohio as follows: the first ash/lilac borer *(Podosesia syringae)* adults were captured in pheromone traps on May 5; the first lesser peachtree borer *(Synanthedon pictipes)* on May 6; and the first peachtree borer *(Synanthedon exitiosa)* on June 12. Bronze birch borer (*Agrilus anxius)* adults began their emergence around May 21.

Damage caused by the buckeye/horsechestnut petiole borer, *Proteoteras aesculuana*, began appearing on buckeyes along the Little Miami River in southwestern Ohio in early April. Larvae of the moth bore into leaf petioles, causing the new leaves to turn black and droop. Infested leaves usually remain attached to the tree and give the appearance of having been damaged by frost or freeze injury. Coupled with the occurrence of a severe freeze in the area in late March, the symptoms presented a diagnostic challenge. However, the presence of the borer could be disclosed by looking for a small hole in the petiole.

The maple petiole borer *(Caulocampus acericaulis)* produced similar damage on maples in central Ohio. This sawfly also causes leaves to discolor and droop; however, larval feeding activity usually causes the leaves to detach. Thus, the main symptom is an accumulation of fallen leaves, which have a short section of petiole attached, with the end usually blackened and shriveled. Adults lay eggs on petioles in May. As the larvae tunnel and feed, the petiole is weakened; the leaves then drop to the ground. The borer is left in the petiole section still on the tree; later the borer drops to the ground and pupates. This insect creates concern but does not typically damage trees, so control is usually not needed.

Lace Bugs

The lace bug "season" was initiated by reports in late April of hawthorn lace bug *(Corythucha cydoniae)* adults leaving overwintering sites and being found on the underside of cotoneaster leaves in northeastern Ohio. By mid-May, high populations of this insect were reported on hawthorns in southern Ohio. Along with attacking its namesake and cotoneaster, the hawthorn lace bug may also be found on pyracantha, flowering quince, crabapple, mountain-ash, and shadbush.

By mid-July, a number of other lace bugs had been observed. These included sycamore lace bug *(Corythuca ciliata)*; oak lace bug *(C. arcuata)* on burr oak; and walnut lace bug *(C. juglandis).* In late August, azalea lace bug *(Stephanitis pyriodes)* and rhododendron lace bug *(S. rhododendri)* were reported to be ravaging their namesakes.

Lace bugs produce characteristic symptoms that include the appearance of numerous small, yellow or whitish spots or stippling on the upper leaf surface. The stippling is caused by the insects' feeding activity on the underside of the leaves. Another symptom is the occurrence of copious deposits of black, varnish-like excrement on the underside of leaves. The lace bugs observed this season caused considerable damage. In particular, the oak lace bug was singled out as producing very noticeable yellowing of leaves of white oaks in central Ohio and burr oak in the southwestern part of the state. The damage was intensified as the result of a late season production of eggs, which spawned an additional generation in late August.

Mites

Eriophyid mites were by far the most prevalent group of mites found in Ohio landscapes this season. In essence, the 1998 season was a repeat of last season (5) with the following mites being found in great abundance — the leaf-epidermis-rupturing pearleaf blister mite *(Phytoptus pyri)* on callery pear; *Vasates aceriscrumena* causing finger-like "spindle galls" on the upper leaf surface of sugar maple; *V. quadripedes* producing globose, pouch-like "bladder galls" on the upper leaf surfaces of red and silver maples; *Phytoptus tiliae* producing "nail galls," or elongated growths with pointed tips, on the upper leaf surface of linden; *Aculops toxicophagus* spawning puckered, irregular, wart-like galls on the lower and upper leaf surfaces of poison ivy; *Eriophyes caulis* generating pubescent, reddish-brown leaf petiole galls on walnut; *Eriophytes tiliae* producing light green, felt-like erineum galls on little leaf linden; and *Acalitus fagerinea* creating green- to yellowish-brown erineum galls on American beech.

However, despite their relative abundance, the aforementioned eriophyids seldom caused enough damage to warrant control efforts. Such was not the case for several other eriophyid mites observed this season.

Rust mites feed by rupturing cells on the surface of plant foliage. Their feeding activity can cause appreciable injury, and damaging populations of three species were observed in several locations in Ohio.

The bronzing effects of baldcypress rust mite *(Epitrimerus taxodii)* were noted in the southern, central, and northeastern parts of the state. The hemlock rust mite *(Nalepella tsugifolia)*, which causes hemlock foliage to turn blue-green, then reddish-brown, and *Nalepella halourga* (no common name), which causes bronzing of the inner needles of Colorado blue spruce, were observed in southern and central Ohio.

These eriophyid rust mites behave as "cool season" mites, and high populations were generally observed during cool months, especially in the fall.

One of the most damaging species of eriophyid mite, the "rosette mite" *(Trisetacus gemmavitians)*, was found to be active on Scotch pine in several Christmas tree plantations in central and southern Ohio. Although this mite has no common name, it is called the "rosette mite" because it induces the formation of a peculiar rosette-like gall.

According to the USDA, Agriculture Handbook No. 573, titled, *An Illustrated Guide to Plant Abnormalities Caused by Eriophyid Mites in North America*, "each rosette consists of a cluster of aborted buds or stunted needles. Typically, the shoots become infested, and the elongation of growing points is inhibited. Numerous buds are clustered at the tip, and the needles that develop from these buds are stunted."

Early-season pesticide application, targeting the rosette mite prior to gall formation, is a recommended control approach; however, results are seldom satisfactory since there is a very narrow application window, and timing dates vary from year to year. The alternative recommendation is to prune and destroy infested rosettes. Of course, this may severely disfigure the tree and limit its value in Christmas tree production.

Although the relatively mild 1997–1998 winter was conducive to continual activity of the cool-season spruce spider mite *(Oligonychus ununguis)*, this mite never reached the expected high populations and associated levels of damage during the spring in most areas of the state. As with 1995 and 1996, large numbers of mites appeared to have been washed from their hosts by heavy spring rains (3, 4). However, populations did recover in the fall, and damage from this resurgence is predicted to be apparent next spring.

The prolonged hot, dry weather over much of Ohio through mid-summer and into early fall proved favorable to the development of high populations of several warm-season mites. Damaging populations of two-spotted spider mite *(Tetranychus urticae)* were observed on a number of landscape plants, including roses and burningbush euonymus. The oak spider mite *(Oligonychus bicolor)* was also common in Ohio this season. Coupled with damage caused by oak lace bug, entire trees had canopies dominated by "washed-out" leaves.

Unusual Sightings

Several insect observations made this season were considered unusual. For example, in late-June, the fuzzy, white, flocculent material produced by immature plant hoppers began to show up on the distal stems of numerous species of herbaceous perennials and woody ornamentals. Populations throughout Ohio seemed high, and most were concentrated on plants near the ground, making the insects very apparent to home gardeners and landscapers. Although plant hoppers suck plant juices and produce copious quantities of honeydew, they caused relatively little damage. At most, the cottony fluff may reduce the aesthetic appeal of infested plants, but the problem was short-lived. Once the immatures completed their development, the flocculent material easily washed off.

Cockscombgalls or pod galls were observed forming along the midveins on the underside of hawthorn leaves in southwestern Ohio in late April. Each gall contained three to five tiny midge fly larvae. As the season progressed and the galls matured, they became raised, bumpy, and changed from light green to deep red, making them look like a cockscomb. One or more galls were found per leaf, and as they developed, leaf expansion was restricted, causing the leaves to become severely twisted or curled. However, populations appeared to be low, and no significant injury was suspected.

Turf Pests

As with the 1997 season, the 1998 season produced some interesting developments regarding white grub-producing beetles (5). May/June beetle *(Phyllophaga* spp.) adults appeared a little ahead of schedule, bouncing off windows and window screens and shattering the evening calm in early May. Despite their common name, green June beetles *(Cotinis nitida)* arrived within their "normal" calendar-date window. The big, metallic-green beetles emerged en masse and began cruising lawns in southern Ohio, terrorizing backyard gardeners, sunbathers, small pets, and others in late July.

Japanese beetles *(Popillia japonica)* were somewhat unpredictable this season. In Ohio, adults normally emerge from the last week of June through July, and most eggs are laid by mid-August. Once eggs hatch, larvae usually feed and develop to the overwintering third instar stage. Last year, adults emerged over an extended period of time, and the subsequent egg production also occurred over a long period of time. As a result, a high percentage of larvae overwintered in the second instar stage (5).

This year, it first appeared that Japanese beetles would repeat this atypical life cycle. Adults began to appear in southern and central Ohio landscapes in early June and continued to remain on the scene through July, August, and September. This seemed to indicate that Japanese beetle populations were remaining asynchronous in terms of developmental stages, and a percentage of the populations would go through the winter in the second instar larval stage rather than third instars, the usual overwintering stage in Ohio.

However, by October, most Japanese beetle grubs were in the third instar stage. Speculation on how this developmental realignment occurred centered on the dry conditions experienced over much of Ohio from August through October. The beetle lays dehydrated eggs, which must absorb water from the environment. Without water, the eggs fail to mature and they die. It was theorized that eggs laid late in the season failed to produce the expected late developing larvae that would be overwintering this year in the second instar stage.

Bluegrass billbug *(Sphenophorus parvulus)* made a dramatic "comeback" in Ohio this season. This insect has been almost nonexistent for a number of years. Populations were high throughout the state, with heavy damage occurring in late June; however, the problem was often misdiagnosed as drought injury. Chinch bug *(Blissus leucopterus)* populations also rebounded from a number of "down" years, with lawns in southwestern Ohio showing severe browning from feeding by this insect in late July and August.

Household and Nuisance Pests

The "usual suspects" once again appeared on Ohio doorsteps, seeking entry points for overwintering. These included gnat-like hackberry psyllids *(Pachypsylla celtidismamma)*, boxelder bugs *(Boisea trivittatus)*, and multicolored Asian lady beetles *(Harmonia axyridis)*. In September and October, masses of Asian lady beetles collecting on the outside walls of Ohio homes were one of the most common subjects of telephone calls to Extension offices.

Ground bees also accounted for telephone calls regarding nuisance problems. Several species of ground bees create nests by burrowing in the ground. These ground bees are also called mining bees or digger bees. Unlike honey bees, ground bees are solitary and do not form social colonies. However, nests may be close together when soil conditions are suitable, and these collective gatherings are sometimes referred to as "colonies" although there is no caste system involving "workers" and a common queen. Instead, each burrow is constructed by an individual female.

Burrows vary between species of ground bees, but most are about one-quarter inch or smaller in diameter and are surrounded by a mound of loose soil, which may rise to a level of one to two inches above the ground. Ground bees are not aggressive and seldom sting. Several species of ground bees are important pollinators, while others provision their burrows with insects and are important biological control agents; thus control is generally not recommended unless a serious threat is perceived.

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Ornamental Disease Summary for Ohio: 1998

James A. Chatfield, Nancy J. Taylor, Joseph F. Boggs, Jane C. Martin, Gary Y. Gao, Pamela J. Bennett, Randall A. Zondag, and David E. Dyke

This summary was developed from observations by the authors throughout the 1998 season, published reports from Ohio State University Extension's *Buckeye Yard and Garden Line (BYGL)*, and records from The Ohio State University's C. Wayne Ellett Plant and Pest Diagnostic Clinic (PPDC). It was a typical year for most disease problems, with wet spring weather resulting in many early problems, but dry mid-summer conditions moderating secondary infections for many diseases. We had all the usual suspects — rust diseases, *Verticillium* wilts, powdery mildews, and Phytophthora root and crown rots in poorly drained sites. Some additional phytopathological comments on the season of 1998 follow.

1. New Disease Reports for Ohio

New disease reports for Ohio, confirmed in 1998 by the PPDC include:

- Anthracnose (*Colletotrichum* sp.) on calendula (*Osteospermum* sp.).
- Anthracnose (*Colletotrichum* sp.) on European wild ginger (*Asarum europaeum*).
- Armillaria root rot (*Armillaria mellea*) on lilac (*Syringa* sp.).
- Black root rot (*Thielaviopsis basicola*) on columbine (*Aquilegia* sp.).
- Black root rot (*Thielaviopsis basicola*) on Rose-of-Sharon (*Hibiscus syriacus*).
- Cenangium dieback (*Cenangium ferm-ginosum*) on Japanese red pine (*Pinus densiflora*).
- Cylindrosporium leaf spot (*Cylindrosporium* sp.) on weeping white mulberry (*Morus alba pendula*).
- Entomosporium leaf spot (*Entomosporium* sp.) on serviceberry (*Amelanchier* sp.).
- Impatiens necrotic spot virus on coleus (*Coleus* x *hybridus*).
- Impatiens necrotic spot virus on lemon balm (*Melissa officinalis*).
- Impatiens necrotic spot virus on primrose (*Primula* sp.).
- Needle rust (*Coleosporium* sp.) on loblolly pine (*Pinus taeda*).
- Phytophthora root rot (*Phytophthora* sp.) on daylily (*Hemerocallis* sp.).
- Phytophthora root rot (*Phytophthora* sp.) on Japanese anemone (*Anemone* x *hybrida*).

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- Pythium root rot (*Pythium* sp.) on columbine (*Aquilegia* sp.).
- Sclerotinia stem rot (*Sclerotinia sclerotiorum*) on daphne (*Daphne* sp.).
- Sclerotinia stem rot (*Sclerotinia sclerotiorum*) on European wild ginger (*Asarum europaeum*).
- Septoria leaf spot (*Septoria* sp.) on trumpet vine (*Campsis taglibuana*).
- Southern stem and root rot (*Sclerotium rolfsii*) on crabapple (*Malus* sp.).

2. Apple Scab and Frogeye Leaf Spot Diseases on Crabapple

Like almost everything else this year, apple scab (*Venturia inaequalis*) got started earlier. Dr. C. Wayne Ellett, professor emeritus in plant pathology at The Ohio State University and the man for whom the PPDC is named, noted primary scab lesions on crabapple leaves in the central Ohio area in late April. Dr. Ellett reported that this was the earliest that he ever remembered seeing scab symptoms, and that typically early infections do not result in observable symptoms until the first weeks of May.

Primary scab is caused by sexual fungal spores that developed in the spring on overwintered leaves and fruits. Secondary scab then occurred and recurred throughout the spring and into the summer, from infections by asexual spores that developed in the early scab lesions.

For many areas of Ohio, relatively dry weather in late spring and in the summer resulted in a little less scab in 1998 than in most years. For information on scab incidence of various crabapple taxa in 1998, see the article on scab evaluations in this ornamentals special circular.

Frogeye leaf spot (*Botryosphaeria obtusa*) on crabapple was often mistaken for apple scab, especially when seen from afar when yellow leaves littered the ground. The symptoms of the two diseases are quite different, however. Instead of the olive-green fungal growth and later grayish to brown scab lesions on the leaves with apple scab, frogeye leaf spot starts with circular brown leaf spots with purple margins. Some spots gradually enlarge at some points along lesion margins, resulting in lobed lesions around the original spot, developing a concentric layered effect with brown areas around the now grayish original center. *Voila* — to some people, this looks just like a frogeye.

The same fungus also causes a black rot of fruits on apple and crabapple and black rot cankers on woody stems of many plants. For control, keep plants as healthy as possible with good pruning, fertilization, mulching, and watering practices. Consider early fungicide sprays if the leaf spot disease gets out of hand on a particular crabapple cultivar over the years and check before you assume that leaf drop is due to scab on a reportedly scab-resistant crabapple.

3. Anthracnose Diseases

For the third straight year, environmental conditions during leaf emergence on sycamores, ashes, dogwoods, and oaks were cool and wet, and this predictably resulted in considerable infections from the anthracnose fungi (*Gloeosporium* sp., *Discula* sp.) that infect these trees. Relative to sycamore anthracnose, Dr. Bobby Joyner of TruGreen-Chemlawn noted it was "the worst he has ever seen."

Despite the early severity of the various anthracnoses, fungicide applications for anthracnose on shade trees can be problematical for the following reasons:

1. Often coverage is very difficult due to the size of the tree.
2. Control of infections is reliable only with preventive applications and often infec-

tions have already occurred by the time applications are considered.

3. As the season progresses, leaf tissue is less susceptible to infection.
4. As temperatures warm, the conditions are also less favorable for infection.

Most trees infected this year re-leafed and appeared to recover well, with the exception of flowering dogwoods with the more serious dogwood anthracnose disease caused by *Discula destructiva.* This fungus moves back into stem tissue readily and can kill flowering dogwoods, especially if they grow in dense shade conditions.

4. Sphaeropsis Tip Blight of Pines

This fungal disease (*Diplodia pinea* or *Sphaeropsis sapinea*) continues to be a major problem on Scots, Austrian, red, and mugo pines in Ohio. Here are some key things to keep in mind relative to this disease.

- Sphaeropsis tip blight is the same disease as Diplodia tip blight. The only difference is an updating of the Latin name of the fungus involved in the disease.
- Infections occur during initial candle emergence in the springtime; therefore protective fungicide applications should be made during the mid-spring period just as new growth emerges.
- Environmental conditions favoring disease development include wet weather and root-stressed plants; therefore, site two- and three-needled pines where there is good soil and air drainage.
- Pruning during dry weather can help remove infested tissue but is not sure-fire, since the fungus also overwinters on infected cones and on needles that have fallen from the tree.
- Pines younger than 15 years of age and older pines with higher canopies seem less affected by this disease.

5. Rose Black Spot

Rose black spot (*Diplocarpon rosae*) got off to a roaring start in the spring of 1998, but in most cases was not severe through the summer, due to dry conditions in much of Ohio.

There were exceptions to this, especially when droughty conditions pressured horticulturists into use of sprinkler irrigation. With frequent water on the leaves, the disease triangle of susceptible rose varieties, presence of the black spot pathogen, and an environment conducive to disease were all met, and in some cases disease incidence was phenomenal.

6. Pachysandra Problems

In early spring many pachysandra plantings exhibited considerable leaf scorching, especially at the tips of leaves. The problem appeared to be due to winter desiccation injury, but it was often misdiagnosed as Volutella blight (*Volutella pachysandricola*).

Further confusing the issue was that this type of desiccation injury to leaf tissue makes it more susceptible to infection from the Volutella fungus. Sure enough, as spring progressed, many pachysandra plantings developed considerable Volutella blight. Fortunately, with drier summer weather, this disease became less prevalent, and by fall it was actually difficult to find Volutella samples for plant diagnostic clinics.

Symptoms of Volutella blight and stem canker include tannish to greyish colored target-like leaf blotches, followed by stem blackening and the presence of salmon-colored sporulation of the fungus on dying stems during wet conditions.

Removal of badly infected and dead plants, limiting overhead irrigation, protective fungicide sprays during periods of active plant growth, proper fertilization, and hopefully drier weather are all key elements for control of this disease. High mowing of badly infected areas and removal of diseased tissue is sometimes the best way to renovate plantings.

7. Phomopsis Dieback of Vinca

There were numerous reports this year of Phomopsis dieback (*Phomopsis* sp.) on vinca. This fungal disease causes the shoot tips to turn dark brown, wilt, and die back to the soil surface. Some stems become black in color, and small, black fruiting bodies of the fungus may erupt through the stem's surface. Wet spring weather and overhead irrigation favor disease development.

As with other groundcover diseases, control involves debris removal in early spring, removal of infected plants, stand thinning, and proper fertilization. Fungicides labeled for control of this disease include copper (i.e., Phyton 27 or Kocide) and mancozeb (i.e., FORE). However, treatment should begin at bud break and continue once a month until plant growth slows in mid to late summer.

8. Bacterial Leaf Spot of Zinnia

This common disease of zinnia (*Xanthomonas nigromaculans* f.sp. *zinniae*) first appears on zinnia leaves as diffuse, translucent, circular spots, 1–2 mm in diameter, surrounded by large chlorotic halos. Under wet conditions, the lesions slowly enlarge to about 5 mm across, becoming reddish-brown in the center and angular in shape. The lesions may coalesce into areas 0.5–1.0 cm long and develop into ragged patches of decaying tissue. When the humidity is very high, the disease may produce small brown spots on the flowers. If infection is severe, the flower heads are seriously disfigured and may decay completely. Diseased plants should be destroyed.

9. Tar Spot of Maple

This fungal disease (*Rhytisma* spp.) seemed much more prominent in Ohio this year, especially in northern Ohio sites. It is often noted that this summer and fall foliar disease of maples is spectacular but relatively harmless to plant health, but the size (quarter size and larger) and frequency of the spots this year still caused concern. Symptoms include black, tarry spots on upper leaf surfaces, associated with yellowed areas on the foliage.

Often these spots are few and almost unnoticeable overall, except to phytopathological afficionados who are looking at individual leaves. At other times, the damage is much more prominent, noticeable to even the casual homeowner observer from afar.

The key to the more severe outbreaks of tar spot appear to be sheltered, moist sites with poor air movement, which favor survival and development of the *Rhytisma* fungus. Some speculated that the seemingly higher incidence of tar spot in 1998 was attributable to mild winter temperatures during the winter of 1997–1998, resulting in higher than usual winter survival of the fungus.

10. Plum Black Knot

This is a common fungal disease (*Apiosporina morbosa*) on plums (other hosts include flowering almonds, cherries, and other members of the Prunus genus). This disease is characterized by black warty growths on the stems and can ultimately result in death of the plant if the disease is not controlled over the years.

On susceptible plants, infected stems should be pruned out at any time, and preventive fungicide sprays should be applied in the spring at flower bud break and continue through the early summer at seven- to 10-day intervals. Fungicides containing thiophanate-methyl, chlorothalonil, and captan can be used for black knot control.

11. Guignardia Leaf Blotch of Aesculus

The reddish-brown leaf blotches and leaf drop caused by the *Guignardia* fungus occurred on buckeyes and horsechestnuts throughout Ohio again during 1998, but damage from this disease was again confused with simple physiological leaf scorch caused by drying conditions. To help distinguish between Guignardia blotch disease and simple physiological leaf scorch on Aesculus, use a hand lens to check for tiny black pimple-like fruiting bodies of the *Guignardia* fungus present within the blotched areas.

In 1999, a number of Ohio State University horticulturists and plant pathologists will be doing a survey of various buckeye and horsechestnut taxa to check for relative incidence of leaf blotch disease and leaf scorch problems.

12. *BYGL*osophies

At the end of each weekly *BYGL*, the authors try to include a meaningful and/or humorous quote for the edification of *BYGL* readers. Now, to conlude this disease summary, here are a few favorite *BYGL*osophies from 1998.

- "The difference between a gun and a tree is a difference of tempo. The tree explodes every spring."

  — Ezra Pound

- "I consider every plant hardy until I kill it myself."

  — Peter Smithers

- "The greatest service which can be rendered by any country is to add a useful plant to its culture."

  — Thomas Jefferson

- "Let us permit nature to have her way. She understands her business better than we do."

  — Michel de Montaigne

- "Nature writes. Gardeners edit."

  — Roger Swain

- Finally, from OSU Extension's Erik Draper:

  "Plant 'em high — watch 'em die.

  "Plant 'em low — never grow.

  "Plant 'em right — sleep at night."

Weed Problems in Ohio Turf, Landscapes, and Nurseries: 1998

Gary Y. Gao, Joseph F. Boggs, Pamela J. Bennett, Jane C. Martin, James A. Chatfield, Mary Ann Rose, Joseph W. Rimelspach, Randall H. Zondag, John R. Street, and William E. Pound

Summary

Weeds such as crabgrass, roughstalk bluegrass, yellow nutsedge, dandelions, Canada thistle, poison ivy, ground ivy, common purslane, galinsoga, and pokeberry were reported to cause major problems in Ohio landscapes and nurseries. This report is a compilation of the noteworthy weed problems and their controls discussed during *Buckeye Yard and Garden Line (BYGL)* conferences that occurred weekly, from April to October, in 1998.

Discussion

Crabgrass (*Digitaria* spp.)

Because of warmer than normal temperatures in March, many lawn-care professionals called Ohio State University turf specialists concerning the cutoff dates for applying preemergent herbicides to control crabgrass. The approximate dates for this application are estimated to be March 1 to April 1 for southern Ohio, March 15 to April 15 for central Ohio, and April 1 to May 1 for northern Ohio. During the second week of April, the OSU Extension turf specialists indicated that those dates were right on the mark after taking soil temperature readings in Columbus.

The first crabgrass seedlings of spring 1998 were spotted on April 17 at Ohio State's Turf Research facility in Columbus. At that time, the crabgrass seedlings were in the single-leaf stage and were only found in bare spots and areas of limited turfgrass cover. Once germination begins, it generally continues over the following 10–12 weeks. Annual grass weed control products such as pendimethalin, Team, Dimension, and Barricade will generally provide 100 or more days of residual control, assuming the treatments were properly applied and timed.

Crabgrass reached the three- to five-leaf to first-tiller stage in central Ohio in the second week of June. Two products are recommended for postemergent control by professional applicators. Dimension (dithiopyr) can be applied for a short period and is effective until the first-tiller stage. MSMA can be used for one- to three-tillered crabgrass. Acclaim and Acclaim Extra

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(fenoxaprop-ethyl) provide control as late as the two- to three-tiller stage. Soil moisture must be adequate for rapid growth of both crabgrass and turf. A word of caution with Acclaim; the turf can be discolored and/or stunted if the applicator overapplies the product and if soil moisture is low.

Roughstalk Bluegrass (*Poa trivialis*)

Roughstalk bluegrass, a light, apple-green colored grass, is generally found in damp and shady areas. It has a tendency to mat down, has a musty odor, and is stoloniferous. Roughstalk bluegrass went dormant and turned brown with high temperatures in early July of 1998. Even with adequate irrigation, this species has a tendency to go dormant during hot periods but resumes growth with the return of lower temperatures. In 1998 there were many reports of brown areas in home lawns and golf courses that were, in fact, *Poa trivialis*.

Yellow Nutsedge (*Cyperus esculentus*)

Yellow nutsedge "stuck out like a sore thumb" in many lawns in 1998. Nutsedge is easy to identify; the stems are erect, triangular in shape, and yellow-green in color. Blades are about one-half inch in width and have a thick mid-vein and waxy coating. Nutsedge produces many nut-like tubers and rhizomes, which, in turn, produce new plants.

Unlike other lawn weeds, this weed is a member of the sedge family and requires the use of specific herbicides for satisfactory control. Nutsedge should be controlled when it is at the three- to eight-leaf stage and actively growing. Two professional products are available for use. Bentazon (i.e., Basagran) requires thorough leaf coverage; delay mowing for three to five days after application. Add a spreader-sticker for improved efficacy. A repeat application may be needed 10 to 14 days later. Halosulfuron (i.e., Manage) can be applied at the three- to eight-leaf stage; use a surfactant as directed. Total kill occurs in three to five weeks.

Dandelions (*Taraxacum officinale*)

Dandelions were in full bloom in southern Ohio by the second week of April. Most homeowners are usually anxious to apply herbicides to dandelions when they see them. However, for effective control, applications of postemergence chemicals should wait until dandelions reach the early puffball stage. Recommended chemicals include those containing 2,4-D, dicamba, or MCPP, or a three-way combination. These herbicides also provide good control of chickweed.

Canada Thistle (*Cirsium arvense*)

Canada thistle, a prolific seed producer, was visible in landscapes across Ohio in April. It propagates from underground rootstocks and will sprout from any root pieces left after weeding. Theoretically, it can be eradicated by hand-pulling or mowing at least three times a season. But timing is everything and on a practical basis, this is difficult to accomplish. Herbicides can save a lot of labor. A 2% solution of glyphosate (e.g., Roundup) is effective, but usually more than one application is necessary. In landscape beds, glyphosate needs to be applied selectively with a wick applicator or some other method of wiping it on, using at least a 30% solution. Bentazon (Basagran) does a fair job on Canada thistle, while dichlobenil (Casoron) provides control in some woody ornamentals.

Poison Ivy (*Rhus radicans*)

Poison ivy was in full bloom in Columbus during the second week of May. The clusters of delicate, cream-colored flowers are attractive. However, it pays to be able to identify this plant and avoid it. Poison ivy has a characteristic compound leaf consisting of three leaflets, two- to four-inches long, and dull or glossy green with pointed tips. The leaves are arranged alternately on the stems. In contrast, Virginia creeper, a nonpoisonous vine often mistaken for poison ivy, has five leaflets radiating from one point of attachment.

Three methods were recommended to eradicate poison ivy in ornamental beds. They include hand (gloved) pulling or grubbing when the soil is moist; severing the vine and then treating the regrowth with a herbicide; or applying a herbicide to individual leaflets. Glyphosate can be applied to new shoots that emerge from the base of old plants. Repeat applications to treat regrowth may be necessary.

Ground Ivy (*Glechoma hederacea*)

Ground ivy was reported to "grow like mad" in home lawns in early August. Ground ivy is also called gill-over-the-ground and creeping Charlie. This perennial member of the mint family is a weed problem in turf and ornamentals. It has a blue flower and a distinctive odor when the leaves are crushed. One of the better identification features is the scalloped edge of the round leaves. Acting as a vine, it moves across grass areas, rooting from the nodes as it travels. Application of herbicides containing 2,4-D, dicamba, or MCPP, or a combination of these materials, will provide good control, but do not apply these materials when temperatures are above 85°F.

Common Purslane (*Portulaca oleracea*)

Purslane is a summer annual with opposite leaves. Each pair of leaves is rotated around the stem 90 degrees from the previous pair. Leaves are wedge-shaped and taper toward the base, and are thick, fleshy, and glabrous. Stems are prostrate and reddish. Mechanical removal of the weed is the best option.

Galinsoga (*Galinsoga parviflora*)

Galinsoga was a common weed in vegetable gardens this year. Its other common names include gallant soldier, quickweed, or water weed. Galinsoga has become an important and serious weed affecting many low-growing vegetables such as cole crops, salad crops, onions, peppers, and many vine crops. Galinsoga is an erect, multi-branched annual growing to a height of two feet. The upper parts of the plant have slender, slightly hairy stems. Galinsoga is a member of the Composite family, which has many flowers grouped together so that they appear to be a large single flower. Galinsoga has several small flower heads at the end of each branch. Each flower head has four or five white ray flowers surrounding numerous yellow disk flowers.

Pokeberry (*Phytolacca americana*)

Gardeners, landscapers, and nature buffs found pokeberry or common pokeweed growing in rich, low-ground pastures, along roadsides and borders of fields, and as an occasional weed in landscapes. This large perennial can grow as high as nine feet from its thick, fleshy taproot, with green or reddish branching stems. Leaves are alternate on the stem, oblong in shape with entire margins, and lower leaves can be a foot in length. Flowers form on branched racemes at or near the ends of stems, and the fruit is a dark purple, many-seeded berry with red juice. Fruit ripens in August.

Pokeberry is a poisonous plant; all parts are considered poisonous. The raw berries are attractive to children, but are highly toxic and potentially fatal. This is a plant gardeners and landscapers should eliminate from properties, if found, to avoid unfortunate incidents.

Herbicide Updates

Roundup Pro

BYGL readers were reminded that Roundup Pro is not the same as Roundup. The new Roundup Pro is Roundup with a surfactant that makes the product work faster on targeted plants. Many users are finding that Roundup Pro is causing damage to plants where the Roundup did not. It is suggested that anyone using Roundup Pro should target and apply the product ONLY to the plants to be controlled. The surfactant increases penetration of the active ingredient through any green tissue, including young bark.

Roundup Pro injury to plants resulted in stunting and discoloration. In some plants, where buds are treated, they may never grow out of the injury. Over-the-top applications with this product are not recommended. Prevent drift and only mix suggested levels of the product at label rates. Do not apply this product to the point of run-off.

Preen Product Line

Greenview's Preen is a pre-emergent granular herbicide used in many garden settings. There are now three granular products for homeowners in this line.

• "Straight" Preen is for use around numerous ornamentals and for limited use in vegetable gardens. The active ingredient in this product is trifluralin (treflan).

• Preen 'n Green is combined with a 9-17-9 fertilizer.

• Preen for groundcovers is labeled for about 50 plants. The active ingredient in Preen for groundcovers is 2.3% 5-ethyl dipropylthio-carbamate, or eptam (EPTC). Both treflan and EPTC have low stability in soil and are readily lost to volatilization if not incorporated. Also, according to Ohio State University Extension Bulletin 867, *Controlling Weeds in Nursery and Landscape Plantings,* the length of pre-emergence control for these products is relatively short. They control annual grasses and some annual broadleaved weeds. EPTC controls a few perennial weeds, including yellow nutsedge and quackgrass.

Professional Preen is a fourth product in the line for professional landscapers and nursery operators. Professional Preen (2.5G) contains 2.0% trifluralin + 0.5% isoxaben. This product contains the same active ingredients as Snapshot 2.5G.

Other Herbicide Information

Another new granular product is Pre Pair, a granular herbicide that contains 4% napropamide + 2% oxadiazon. Products that have been cancelled and will be available only as long as supplies last include Dacthal and DeMoss.

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3. North Central Regional Research Publication No. 281. *Weeds of the North Central States.*

4. Herbicide Damage CD. Mike Dana and others at Purdue University developed a new CD titled "Picture the Damage! Herbicide Damage Symptoms on Ornamentals," which has more than 500 four-color images of herbicide damage from 12 different herbicides on 21 different ornamental plants. The cost of the CD is $39.95.

For information and to order, contact the Agricultural Communication Service, Media Distribution Center, 301 South Second Street, Lafayette, IN 47901-1232. Phone: 317-494-6794; Fax: 317-496-1540.

Summary of Turf Cultural and Disease Problems: 1998

Gary Y. Gao, Joseph F. Boggs, Pamela J. Bennett, Jane C. Martin, David E. Dyke, Joseph W. Rimelspach, Barbara Bloetscher, John R. Street, William E. Pound, and James A. Chatfield

Summary

This article is compiled from reports of turf cultural and disease problems as well as recommendations in the weekly *Buckeye Yard and Garden Line (BYGL)* throughout the year of 1998. Common turf diseases in 1998 included pink snow mold, leaf spot, red thread, necrotic ring spot, powdery mildew, brown patch, Pythium blight, fairy rings, dollar spot, rust, and gray leaf spot. Many turf problems were related to unusual weather conditions in 1998. Turfgrass seed head production, turf quality, summer turf management, lawn mowing, and turf reseeding are also discussed.

Discussion

Lawn Mowing

Lawn mowing is one of the most important turf management practices. Mowing turfgrass too short in early spring is more harmful to root growth than mowing short at any other time because the leaves return photosynthates (food) to the roots. Leaf blades that are continuously mowed too short result in short, meager roots. The cool season grasses form most of their roots in spring and again in fall and late fall. Mowing turfgrass too short stresses the entire plant and reduces root development significantly. Mow frequently and never remove more than one third of top growth at any one time.

Early-Season Turf Diseases

Extended cool, wet weather in early spring favored many turfgrass diseases including snow mold, leaf spot, and red thread. *BYGL*ers stressed that proper mowing was one of the main keys for disease prevention. Fungicide recommendations for these diseases are found in Ohio State University Extension Bulletin L-187, *1998 Management of Turfgrass Pests.*

Heavy Seed Head Production

The cool wet weather in mid-May and resultant infrequent mowing prompted heavy seed head production in turfgrass, especially Kentucky bluegrass and perennial ryegrass. Tough stems from seed heads did not cut well, significantly reducing mowing quality. Much variation in seed head production was evident among Kentucky bluegrass cultivars.

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Red Thread (*Laetisaria fuciformis*)

Red thread continued through early June due to the cooler temperatures and damp conditions. However, as the moisture dropped, severely infected leaves browned and died, leaving tan brown dead spots. This disease produces irregular patches of blighted or browned grass ranging in size from two inches to three feet in diameter. Water-soaked spots appear first, followed by general drying out of the infected tissue. The tissue fades to a tan color. Under damp conditions, leaves may be covered with a pink, gelatinous, thread-like growth of fungus. This growth may extend from the leaf tips to nearby plants.

Control measures include a good fertility program, mowing a bit shorter to promote rapid drying of affected areas, and a fungicide program if the problem is severe. At times the stressed turf becomes susceptible to summer diseases.

Dry Weather in Late May and Early June

Hot days came in mid- to late May. *BYGL* readers were reminded to start implementing summer turf-management practices. Mowing height should be raised to 2-3/4 to 3 inches and mowing frequency decreased to every seven to eight days as turf growth rates lessens. To minimize stress on the turfgrass and the mower operator, mow during morning or late afternoon hours instead of in the heat of the afternoon. Readers were also referred to Ohio State University Extension Fact Sheet HYG-4029-96, *Managing Turfgrass under Drought Conditions* for more turf management tips.

Lawn quality continued to decline in early June 1998. In many areas, dry-weather injury appeared as localized browning on slopes and under trees and as streaking from mower injury. Grass on compacted, heavily thatched, and poor soils browned. In some parts of Ohio, lawns became dormant.

Rhizoctonia Blight or Brown Patch (*Rhizoctonia solani*)

Rhizoctonia blight became a serious problem in early July, especially on tall fescue. Blades first appeared water-soaked and dark bluish-green. Then the leaves withered and turned brown. Lesions were evident along the leaf margins. This disease requires the presence of moisture on the leaves for the fungus to spread to healthy plants. Turf growing under high nitrogen is more susceptible.

Mowing height had a significant effect on brown patch on tall fescue this year. Recent observations at the Clark County Regional Turf Education Plots revealed significantly more brown patch (*Rhizoctonia solani*) in the high-cut (3") versus the low-cut (1.5") tall fescue plots.

In the higher-cut plots, the canopy stayed wet much longer, providing the perfect environment for the fungus to spread, resulting in extensive damage to the leaves and large brown patches in the turf. In the shorter-cut plot, the canopy dried rapidly, which inhibited fungal growth and subsequent turf damage. However, during dry periods, the high cut is recommended.

Pythium Blight (*Pythium aphanidermatum, Pythium ultimum*)

Pythium was active in early July on golf courses and on newly seeded, heavily watered lawns. Pythium requires day-time temperatures of 90°F and night-time temperatures of 70°F for symptoms to appear. Since Pythium can kill turf, controls are a must to prevent further damage.

Pythium blight, brown patch, and dollar spot can look similar to both the untrained or trained eye during early morning hours when mycelium are present. Often, suspected cases of Pythium blight were misdiagnosed. Brown patch and dollar spot usually do not kill turf, although they damage leaf tissue and reduce quality;

therefore, it is not always necessary to apply expensive fungicides to control these two diseases. When in doubt, send samples to Ohio State University's C. Wayne Ellett Plant and Pest Diagnostic Clinic (PPDC) for diagnosis.

Fairy Rings

Fairy rings became evident in a few central Ohio lawns in early July. This curious phenomenon can be produced by 50 or more species of soil-inhabiting fungi. These fungi grow on decaying organic matter and are often associated with thatchy lawns or areas where trees have been removed.

Fairy rings can take on different patterns, including mushrooms that appear in circles or arcs, as dark green rings, or without mushrooms with a circular area of dead grass. The mushrooms are the fruiting structures of the fungi. The diameter of a fairy ring may vary from three to four feet up to 200 feet, and ring width may range from only a few inches up to two feet in width. Each season, fairy rings may grow a few inches to several feet in diameter. Sometimes fairy rings disappear for a year or more and then reappear.

The darker green ring of grass is due to increased nitrogen that becomes available as the fungus breaks down organic matter in the soil. Brown or thin grass may develop inside the darker green ring; this may be related to drought stress caused by dense growth of underground fungal structures.

Little can be done to control fairy rings, although symptoms can be suppressed. Fertilizing lightly may reduce the contrast between the lawn and darker green ring, as will irrigating with large quantities of water. Total "eradication" includes soil excavation and replacement, killing the grass in the ringed area, and then reseeding. A few fungicides are labeled for fairy ring control, but suppression may only be temporary.

Dollar Spot (*Sclerotinia homoeocarpa*)

In early August, dollar spot was quite heavy in Kentucky bluegrass lawns due to the lack of growth from drought. Although this disease affects bluegrass and tall fescue, it is generally more serious on bentgrass. The disease appears as round, brown, or bleached spots the size of a silver dollar or somewhat larger. Infected grass blades are often a straw-colored tan with reddish-brown margins.

If dollar spot is heavy, three management techniques will help:

- Irrigate to promote growth.
- Fertilize, using a product with at least half of the nitrogen in a slow-release form.
- Wait for the turf to recover.

Dollar spot does not kill the plants, and the lawn will recover under normal growing conditions. A more long-term solution would be to use resistant cultivars during turf installation or renovation. A listing of resistant bluegrass cultivars can be found by visiting the National Turfgrass Evaluation Program website at:

http://hort.unl.edu/ntep/tables.htm

If a more immediate response is desired, homeowners can use fungicides containing chlorothalonil. Golf-course managers can find a list of products labeled for commercial use by referring to OSU Extension Bulletin L-187. An important note — fungicidal applications must be frequent in order to suppress this disease successfully.

Rust (*Puccinia* spp.)

The year of 1998 was a banner year for rust, especially during dry periods. This year, rust was reported in southwestern Ohio as early as May. In general, the same recommendations for managing dollar spot will also suppress rust. However, fungicides available to homeowners contain chlorothalonil, and this usually provides poor control of rust. Triadimefon (e.g., Bayleton) and propiconi-zol (e.g., Banner) are recommended to commercial applicators, if chemical control is necessary.

Gray Leaf Spot (*Piricularia grisea*)

Gray leaf spot, a relatively new disease in Ohio, was reported in mid-August. The rapid wilting, collapse, and death of ryegrass in lawns or fairways may indicate gray leaf spot. It commonly develops in late August under hot, humid conditions. The first confirmed sample of this disease (from northern Kentucky, across the river from Cincinnati) was received August 18 in the C. Wayne Ellet Plant and Pest Diagnostic Clinic. Turf samples suspected of being infected with gray leaf spot should be sent to the PPDC.

Necrotic Ring Spot (*Leptosphaeria korrae*)

Turf samples with necrotic ring spot (NRS) were identified in the PPDC in mid-August. NRS symptoms appear when wet weather is followed by hot, dry periods. The fungus grows during the cool, wet spring months but does not show until the stressed turf suffers from depleted roots and higher water demands. It appears first as small, scattered, circular, light-green to straw-colored patches on Kentucky bluegrass (but also affects annual bluegrass and red fescue).

As the disease progresses, the patches become sunken or crater-like and appear as rings or arcs of dead turf, with a green center of recovering turf, called a frog-eye. To diagnose NRS, examine root and crown tissues. Darkly pigmented (black or brown) fungal threads appear on the surface of the root when viewed through a microscope. Frog-eye symptoms and dark runner hyphae are diagnostic characteristics.

Reseeding Turf

Where frequent irrigation was possible, late August was a good time to begin reseeding home lawns to repair the areas with dead grass or spots infested with perennial weeds such as bentgrass, rough bluegrass, or nimblewill. However, brown turf at this time did not necessarily mean dead turf. Many home lawns had simply gone dormant due to water stress or insect damage.

When renovating areas infested with grass weeds such as bentgrass, rough bluegrass, or nimblewill, it is very important to completely kill the weed before reseeding. Water weeds first and make sure they have ample foliage for herbicide absorption. It is not effective to apply glyphosate (i.e., Roundup) to brown grasses or grasses with very limited leaf surface area. In addition, wait for five to seven days for the herbicide to translocate to the roots for total kill of weed roots. Otherwise, reseeded areas will still look poor since some of the perennial weeds will grow again along with desirable turfgrass.

Refer to Ohio State University Extension Fact Sheet HYG-40-1192 for information on *Turfgrass Species Selection;* HYG-4027-91, *Turfgrass Cultivar Selection;* and OSU Extension Bulletin 546, *Lawn Establishment.*

In addition, the 1997 progress report of the USDA National Turfgrass Evaluation Program was made available in August. It listed the rankings of top-named cultivars, based on quality ratings, for the four prominent turfgrasses in Ohio. This list is available through local Ohio State University Extension offices.

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Wildlife Problems in Ohio Landscapes: 1988

Gary Y. Gao, Joseph F. Boggs, Jane C. Martin, Pamela J. Bennett, David E. Dyke, and James A. Chatfield

Summary

Nuisance pests such as moles, squirrels, chipmunks, woodchucks, mice, raccoons, skunks, and voles caused damage to Ohio landscape plants in 1998. The control measures for each vary greatly. However, the principles of wildlife damage prevention and control are similar. They include physical exclusion, live trapping, relocation of wildlife, alteration of habitats, lethal methods, and use of chemical and physical deterrents.

Introduction

Prevention and control of wildlife damage are an increasingly important part of the wildlife management profession because of expanding human populations and intensified land use. As more people move into previously agricultural areas, people and wildlife merge. People need to learn to deal with wildlife so that they can prevent or minimize damage to fruits, vegetables, trees, shrubs, and lawns. It is important to be aware of ways to handle wildlife problems as they relate to different geographic areas. This report is a compilation of the note-worthy wildlife problems discussed during *Buckeye Yard and Garden Line (BYGL)* conferences that occurred on Tuesdays from April to October in 1998.

Discussion

Moles

Moles were active in 1998, and agents received numerous calls regarding damage in home lawns. Moles caused most of their damage to home lawns in spring, summer, and fall. Moles created surface tunnels as well as mounds of soil, which are the result of digging deeper to build nests or to avoid freezing soils.

While there are many recommendations for controlling moles, trapping with harpoon traps or scissor-jaw traps still remains the only sure-fire control method.

In order to learn about mole control, one must understand the nature and habits of moles. Since they are insectivores, the primary diet is earthworms and other soft insects. They don't have the mouth structures to chew gum and poison baits!

Trapping takes time and patience in order to eliminate moles but is still the best recommendation. Contact your local Division of Wildlife office for information on habits and trapping.

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Squirrels

Squirrels were found in an attic chewing up baskets in April and were also reported to be cutting off branches of ash trees in June. Apparently, they were sharpening their teeth by chewing on tree branches. Recommended control efforts primarily center on trapping (box and cage traps) and relocation. Of course, this can be a time-consuming venture.

Tree squirrels are common residents in the urban forests of Ohio, and they will occasionally nest in attics or walls of homes. The best control option is exclusion; homes should be closely inspected and openings closed with wood, masonry, or hardware cloth. If squirrels cannot be easily excluded, they may be repulsed using naphthalene (moth balls). The granules should be spread on floors and between walls at a rate of 5 pounds per 2,000 cubic feet.

If these methods fail to work, the only alternative is population reduction either through trapping, predation, or lethal control methods (hunting). Though time consuming, live traps can be very effective when baited with peanut butter or whole or halved nut meats. Hunting is not a realistic alternative in urban areas; however, predation from other animals can have some effect.

Chipmunks, Woodchucks, Mice, and Voles

Chipmunks, woodchucks, mice, and voles constituted the vast majority of wildlife calls. Frequently, chipmunk problems were associated with bird feeders attracting the little critters. Moving the feeders at least 15 to 30 feet from the nearest structure or cover may help to mitigate damage. Damage may also be avoided by not planting groundcover, trees, and shrubs in a continuous fashion, thus connecting wooded areas to flower beds and structures.

Woodchucks can be discouraged from sampling the goodies in your garden by heavy mesh fencing. The fence should be at least three- to four-feet high with the top 15 inches bent outward at a 45-degree angle to prevent climbing over the top. The lower edge of the fencing should be buried 10 to 12 inches in the ground or bent at an L-shaped angle leading outward and buried in the ground 1 to 2 inches to prevent burrowing.

Numerous voles or mice were reported to scurry around the base of junipers. The lower branches and stems of the plants were extensively gnawed upon by these rodents.

Raccoons and Skunks

Raccoons or skunks damaged turf by pulling up or rolling back sod. The BugDoc, Dave Shetlar, reported in his August 24, 1998, issue of *The P.E.S.T. Newsletter* (Vol. 7, No.12), that earthworms, grubs, and even periodical cicada nymphs are part of raccoons' or skunks' diet.

Young raccoons commonly learn to forage for themselves in middle to late summer and roll up the sod for insects, since other food sources are less available during the periods of dry weather.

Useful Resources

***Prevention and Control of Wildlife Damage*, University of Nebraska.**

This publication is available in both book and electronic format (CD-Rom).

Copies of the book are $40.00 each plus $5.00 shipping. CD-Rom copies of the publication are $40.00 each plus $3.00 shipping. Copies of the book plus CD-Rom are available at a discount price of $60.00 plus $5.00 shipping.

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Phone: 419-424-5000

Wildlife District Three
912 Portage Lakes Drive
Akron, OH 44319
Phone: 330-644-2293

Wildlife District Four
360 E. State Street
Athens, OH 45701
Phone: 614-594-2211

Wildlife District Five
1076 Springfield Pike, Box 576
Xenia, OH 45385
Phone: 937-372-9261

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Control of Nuisance and Detrimental Molds (Fungi) in Mulches and Composts

Harry A. J. Hoitink and M. S. Krause

Summary

The shotgun fungus, slime molds, and plant pathogens occasionally cause problems when mulches are used in the landscape. Sour mulches and dry woody mulches prepared from trees that readily decompose cause most of the problems. How to manage mulches and composts to avoid problems with these types of fungi is discussed. The best control strategy is to partially compost all mulches before utilization. Mulches should be soaked with water immediately upon utilization to enhance colonization by bacteria and inhibit growth of fungi. Sour mulches should be avoided altogether.

Introduction

Mulches and composts are often used to improve soils and plant health and to control weeds. They improve drainage as they decompose even though the ability of the soil to hold moisture is increased. They lower soil temperature in the summer and insulate roots from cold in winter conditions. Eventually they mineralize, release nutrients for plants, and leave humic substances as residues. Their beneficial side effects gradually disappear unless more mulch or compost is applied.

Generally, these organic materials inhibit undesirable microorganisms such as soilborne pathogens that cause diseases of plants. They also stimulate the activity of many types of beneficial microorganisms, including mycorrhizal fungi. Occasionally, however, microorganisms (primarily fungi) in mulches and composts can become a nuisance and even cause certain diseases of plants.

Whether a mulch or compost provides beneficial or detrimental effects is largely determined by the type of organic matter from which it was produced and the degree to which it was decomposed and treated before its application in the landscape. The temperature, pH, and moisture content of the products also have an effect. The severity of nuisance fungi can be minimized if appropriate steps are taken in time.

Examples of Nuisance Fungi

The shotgun or artillery fungus (*Sphaerobolus*) may cause serious problems. While it decays the mulch, it also produces fruiting structures that resemble tiny cream or orange-brown cups that hold a spore mass resembling a tiny black egg (1/10 inch in diameter). This fungus shoots these spore masses high into the air. They stick to any surface and resemble small tar spots on the leaves of plants or the siding of homes.

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They are difficult to remove, leave stained surfaces, and may result in major aesthetic problems.

Slime molds are another type of nuisance fungus. They first appear as bright yellow or orange slimy masses that may be several inches to a foot or more across. They produce tiny spores that eventually dry out and blow away. These molds, like many others such as stink horns and bird's nest fungi, actually should be considered microbial ornamentals in the landscape. However, some fungi in mulches and composts produce mushrooms, and some of these are toxic to humans. It is a good idea to destroy them when small children have access to the mulched area.

Another fungal problem that is often not identified correctly occurs when mulches are applied too deep (4 to 6 inches) instead of the ideal depth of 1.5 to 2 inches. Deep layers of mulch, particularly if prepared from fresh woody materials, may actually undergo high temperature decomposition during the summer. The result is that the mulch dries out to less than 34% moisture and becomes a dusty mass. Fungi often colonize these dry mulches until they become a water-repelling, moldy chunk of material. Young trees mulched in this way sometimes die from drought even though the homeowner irrigates the area, because water runs off the mulch.

Other Types of Problems

Fresh mulches prepared from trees killed by plant diseases may be colonized by plant pathogens. *Verticillium dahliae*, a fungus that causes wilts and death of many shade trees and ornamental shrubs, can be carried in infested mulch and kill susceptible plants in the landscape. *Rhizoctonia solani*, another plant pathogen that causes damping-off of many types of seedling plants, is actually stimulated by fresh mulches. This pathogen utilizes the cellulose in wood as a source of food.

Short-term composting of mulches in windrows under high-temperature conditions (130–160°F) kills these plant pathogens. Six weeks of composting is sufficient to kill most plant pathogens and avoid their dissemination in mulches or composts.

Mycorrhizal fungi, which are fungi that can form beneficial associations with roots, also are affected by mulches and composts. A shallow layer of wood chips (1–2") or compost improves tree establishment because mycorrhizal development is stimulated by the slow-in-release organic sources of nitrogen and carbon in organic matter. However, a deep layer (4–6") of the same freshly chipped wood has been shown to inhibit the development of mycorrhizae during reforestation. Negative effects on mycorrhizae must be avoided in the landscape, because they are very important in the maintenance of healthy plants.

Compost and mulch producers, landscapers, and homeowners can take measures to minimize fungal problems in the landscape. The type of mulch used, fresh versus composted mulch, the moisture content of the mulch before and during its utilization, the temperature and pH of the mulch before and during utilization, and the depth to which it is applied all play a role. These factors are discussed here.

Mulch Type and Fresh vs. Composted Mulch

Wood products from some trees are more resistant to decay than others and, therefore, cause fewer problems. Bark chips (nuggets) from large mature pine or other softwood trees such as cypress trees contain mostly lignin (dark material in bark), wax, and protected cellulose that resist decay. On the other hand, ground wood wastes from young trees of the same species rot quite readily because the cellulose in such bark and wood products is not yet protected from decomposition by lignin waxes or tannins.

Hardwood tree bark (oak, maple, and others), even from large trees, contains a large concentration of cellulose that is not protected from rotting. Therefore, hardwood bark mulches, like ground wood from almost all tree species, rot readily and cause most of the nuisance mold problems in the landscape. The finer the product is ground, the more severe the problem can be! These materials are low in nitrogen content. The fine particles (less than 3/4" diameter) in such mulches cause nitrogen immobilization in soil. The microflora that decomposes the wood particles takes up the nitrogen required for growth of plants. The result is that the plant becomes starved for nitrogen. Some mulch producers screen all particles smaller than 3/8" out of high-wood content or hardwood-bark mulches, which avoids most of the nitrogen immobilization problem.

The best way to avoid all these problems and bring about beneficial effects by mulching is to add nitrogen to woody and hardwood-bark products followed by composting to lower the carbon to nitrogen ratio. Blending of grass clippings with wood wastes before composting is one way to achieve this. Addition of poultry manure or urea to supply 1.2 lbs. available nitrogen per cubic yard of material satisfies the nitrogen need also. Some landscapers add 10 to 15% by volume composted sewage sludge to hardwood bark or wood wastes, and this makes an ideal product that has performed very well in landscapes.

These amended products should be composted at least six weeks. This process kills plant pathogens, eggs of insect pests, and produces a nitrified product that releases plant nutrients rather than ties up nitrogen. As mentioned previously, the microorganisms that have colonized these products reduce the potential for growth of nuisance fungi and provide control of many plant diseases.

Temperature, Moisture Content, and pH

Landscapers often apply quality mulch products from high-temperature piles (140–160°F) directly into the landscape. The temperature of the mulch is high because of heat produced by growth of microorganisms known as thermophiles during the composting process in storage piles. These microorganisms die soon after the mulch cools to 50–80°F after it has been placed around homes. Because they require high temperatures to survive, they cannot grow and compete with soil microorganisms at the low temperature of mulches in the landscape.

The sudden temperature drop that often occurs after mulch is applied creates what is known as a biological vacuum. This also can occur during bagging of products at producers of mulches, particularly during dry seasons. Mesophiles (low-temperature soil microorganisms) rapidly colonize such mulches. If the mulch is dry, or dries out to a moisture content below 34% during the first day after it is applied (mulches are dusty below this moisture content), fungi become the primary colonizers. This sets the stage for problems later, and the problem becomes most severe in mulches that are applied too deep in the landscape.

After prolonged heavy rains, the dry material colonized by fungi eventually becomes wet. Dry products stored in bags may also become moist as water produced as a result of microbial activity accumulates along the inner surface in bags. Bacteria then rapidly colonize the fungal white mass to induce the formation of fruiting structures by the fungi. The nuisance fungal fruiting structures appear a few days later.

Mold problems occur also when dry products are bagged or applied to dry soils. Dry composts removed from high-temperature piles occasionally cause mushroom problems in bags and also in soils at nurseries.

These moldy products inhibit plant growth in field soils as well as in potting mixes. They also cause wettability problems if dry conditions persist in soil for a few weeks to give fungi a chance to become the dominant colonizers. Plants do not grow well in such moldy soils.

These problems can be reduced by soaking the high-temperature products with water as they are applied in the landscape or bagged. The high-moisture organic matter then becomes rapidly colonized by bacteria during the first few days. These bacteria compete with fungi to reduce the potential for the development of major mold problems. This strategy has been successfully applied over the past decade to hardwood as well as softwood composts and mulches. It has controlled nuisance problems caused by many fungi in various parts of the United States and abroad.

The pH or acidity of the mulch is another important factor. Sour mulches that give off acrid odors may range in pH from as low as 2.5 up to 4.8. Highly acidic mulches are toxic to most plants and promote the growth of fungi. Bacteria that inhibit fungal growth cannot colonize mulches when the pH is lower than 5.2. The low pH and fungal problems are avoided if the raw material is nitrified and composted as described previously.

In summary, water applied at the right time during composting, storage, and mulching can solve most of the fungal nuisance problems. It is best to maintain a water content higher than 40% on a total weight basis. This allows bacteria as well as fungi to colonize the organic matter, and it sets up competition for nuisance molds. The moisture content of most organic products actually can be raised above 50% and not present excessive weight problems during transport.

What To Do Once the Problems Occur

Sometimes very little can be done to control nuisance fungi other than to spade the mulch into the surface soil layer followed by soaking with water. Another option is to remove the mulch and place it in a heap after thorough wetting to allow for self-heating to occur (110–140°F). This will kill nuisance fungi. If fresh dry mulch is placed on top of mulch colonized by nuisance fungi, the problems may occur again the following year or even earlier.

The best control strategy for homeowners and landscapers is to purchase composted products that are low in wood content. Fresh, finely ground woody products should be avoided for many reasons unless composted first. Coarse, fresh woody products are much less likely to cause problems unless applied too deep. It is important to soak all mulches immediately after they have been applied. Generally, mulches should not be applied to a depth greater than two inches. Mulches and composts applied in this manner provide many types of beneficial effects rather than nuisance problems, or worse, plant diseases. Sour mulches should be avoided altogether.

Understanding and Using Degree-Days

Daniel A. Herms

Summary

The development rate of plants and insects is linked directly to temperature. The timing of phenological events, such as emergence of insects and flowering of plants, depends on the weather and can vary by several weeks between years. Recording degree-day accumulation is a valuable tool for quantifying how rapidly heat accumulates and thus for predicting the development of plants and insects.

This report discusses three methods that are commonly used to calculate degree-days from daily maximum and minimum temperatures — the Average, Modified Average, and Modified Sine Wave Methods. Each of the three gives the same result when the daily minimum temperature remains above the specified base temperature (often 50°F). The Modified Sine Wave method is most accurate when the daily minimum temperature falls below the base temperature (as it does frequently during the spring).

A table of degree-day values calculated using the Modified Sine Wave method is presented to facilitate use of this method. Practical application and limitations of degree-day models are discussed.

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Introduction

We have all observed that plants bloom earlier and grow faster during warm years than during cool years. Insects also emerge earlier in warm years. This is because the development rates of plants and cold-blooded animals, including insects, are linked directly to temperature. Unlike warm-blooded animals, they have very limited ability to increase their temperature above that of their immediate environment.

The development of plants and cold-blooded organisms is optimal within a relatively narrow range of temperatures and slows rapidly as the temperature approaches upper or lower limits for development (Figure 1). Development ceases altogether once the upper or lower temperature threshold for development is exceeded. Upper and lower developmental thresholds vary from one species to another, depending on the environmental conditions to which the plant or insect is best adapted.

Year-to-year variation in weather patterns often makes calendar-based scheduling of horticultural and pest management practices inaccurate. For example, many plants bloomed and insects emerged three weeks earlier during the warm El Niño spring of 1998 than they did during the cool spring of 1997 (see the following report on plant and insect phenology). Calculation of degree-days provides a valuable tool for quantify-

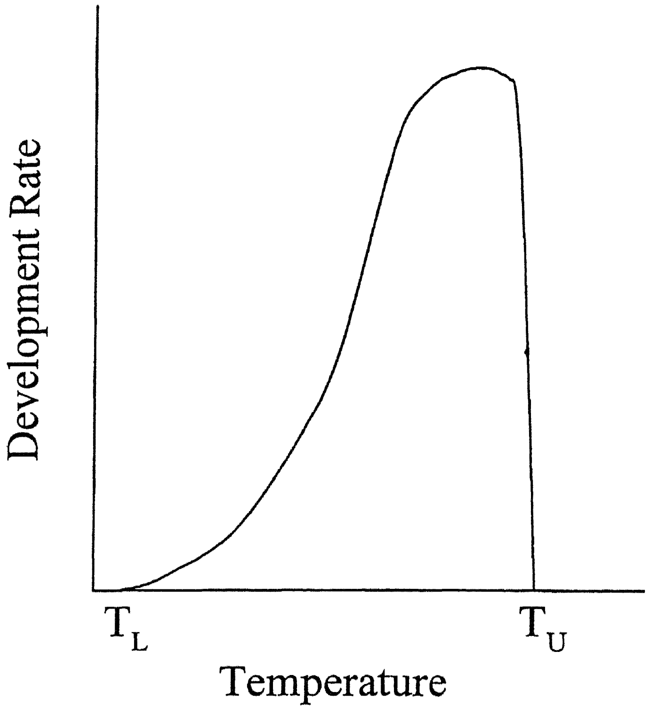

Figure 1. The development rate of plants and cold-blooded animals such as insects is dependent on temperature. Development is most rapid around a narrow range of optimal temperatures and slows quickly at higher and lower temperatures. Development stops altogether when the temperature falls below the lower developmental threshold (TL) or rises above the upper developmental threshold (TU).

ing how rapidly heat accumulates and thus for predicting the development of plants and insects.

What Are Degree-Days?

A degree-day (also referred to as a growing degree-day, heat unit, or thermal unit) is a unit of measure reflecting the amount of heat that accumulates above a specified base temperature during a 24-hour period. One degree-day accumulates for each degree the temperature remains above a specified base-temperature for 24 hours.

It is important to understand that degree-days have no meaning until a base temperature is specified. Ideally, when attempting to predict plant and insect development, the lower temperature threshold for development is used as the base temperature for calculating degree-days. Growth and development stops when the temperature drops below this threshold.

The lower developmental threshold temperature is known only for a few species, but experience has shown that 50°F is a reasonable approximation for many species, and it is commonly used as the base temperature (although other temperatures are commonly used, including 0°F, 32°F, and 42°F). In northern climates including Ohio, the upper temperature threshold for development is not generally exceeded for long enough periods to be an important consideration and is often ignored when calculating degree-days.

Cumulative degree-days refers to the total number of degree-days that have accumulated since a designated starting-date and are calculated simply by adding the number of degree-days that accumulate each day. Any date can be used as the starting-date, but January 1 is most commonly used.

Calculating Degree-Days

There are a number of ways to calculate degree-days, ranging from quite simple to those so complex that a computer is required. The three methods to be discussed here are the Average Method, the Modified Average Method, and the Modified Sine Wave Method. All three methods calculate degree-days from the daily minimum and maximum temperature and a specified base temperature. During a typical 24-hour day, the minimum temperature is usually reached just before dawn and the maximum temperature during mid-afternoon. Figure 2 depicts the temperature pattern for a hypothetical day in which the minimum and maximum temperatures were 45°F and 65°F, respectively. In this example, we have designated the base temperature as 50°F.

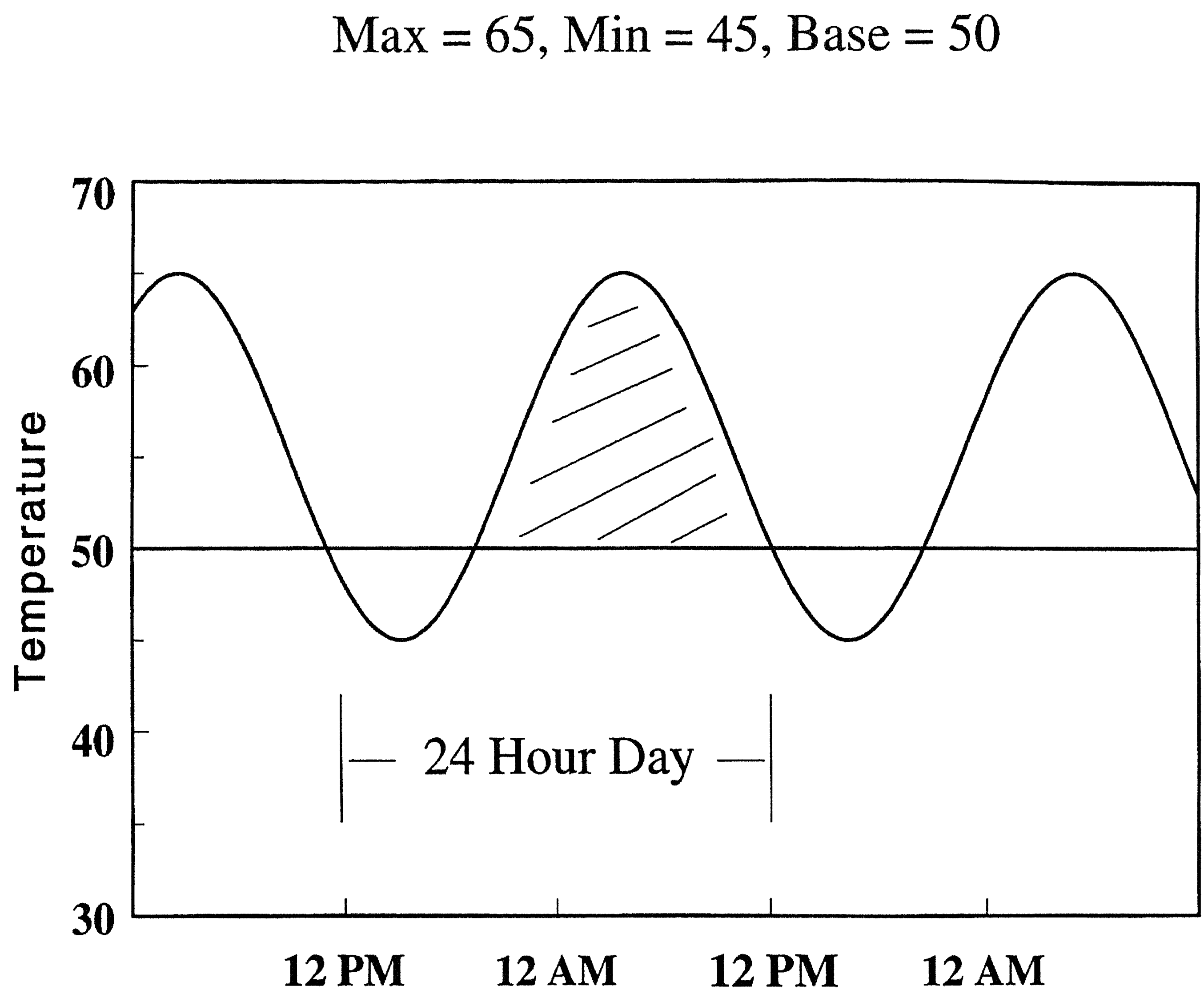

Figure 2. Variation in temperature over the course of a typical day often follows a predictable pattern with the minimum temperature generally occurring just before dawn and the maximum temperature occurring in mid-afternoon. The base temperature in this example has been specified as 50ºF (which is close to the lower developmental threshold for many plants and insects). The shaded area under the temperature curve and above the base temperature represents the amount of degree-days that accumulated during this hypothetical day and can be calculated using the Modified Sine Wave method.

The Average Method

The Average Method is the simplest method for calculating degree-days. Using this method, the number of degree-days for a particular day is calculated by subtracting the base temperature from the average temperature for the day according to this formula:

Degree-days = [(max temp + min temp) / 2] - base temp

Using this method, five degree-days accumulated during the day depicted in Figure 2.

[(65 + 45) / 2] - 50 = 5 degree-days

If the maximum temperature for the day never rises above the base temperature, then no development occurs, and zero degree-days accumulate. (Negative degree-day values are not calculated since the development of organisms does not reverse when it is cold.)

The Modified Average Method

When the daily minimum temperature falls below the base temperature (as it does frequently in the spring), the Average Method can underestimate the number of degree-days actually accumulated by a plant or an insect. This is because development occurs even during the short periods that the temperature is above the base temperature, no matter how cold it may be during the rest of the day. In this situation, the Modified Average Method will calculate a higher number of degree-days and thus can be more accurate.

The Modified Average Method is calculated in the same way as the Average Method, except that the base temperature is substituted for the minimum temperature when the minimum temperature drops below the base temperature (as it does in Figure 2) according to the following formula:

Degree days = [(max temp + base temp / 2] - base temp

Using this method, 7.5 degree-days accumulated during the day depicted in Figure 2, as opposed to five degree-days as calculated using the average method:

[(65 + 50) / 2] - 50 = 7.5 degree-days

The Modified Sine Wave Method

The Modified Sine Wave Method (Allen, 1976) is even more accurate when the minimum temperature drops below the base temperature. However, most people find it too complex to calculate without the use of a computer. This method makes use of the fact that daily temperature patterns closely resemble a sine wave function (if you remember your trigonometry) and determines the amount of degree-days by calculating the amount of area under the temperature curve and above the base temperature (shaded portion of Figure 2).

On days when the minimum temperature remains above the base temperature, this method yields the same result as the Average Method. Table 1 can be used to determine the number of degree-days that accumulate on days that the minimum temperature falls below the base temperature.

Using Degree-Days to Predict Insect and Plant Development

Degree-day models can be valuable tools for predicting insect development and timing pest management practices. Table 2 outlines the steps to follow. The simplest way to construct a degree-day model is to observe a phenological event from one year to the next (for example, adult emergence of bronze birch borer) and note the number of degree-days that have accumulated since the starting date. In Wooster in 1998, bronze birch borer adult emergence first occurred on May 18, after 519 degree-days had accumulated above a base temperature of 50°F since January 1. (See Table 1 in the following report.)

For reasons that will be discussed shortly, the number of degree-days required for a particular phenological event often varies from one year to the next. For example, emergence of bronze birch borer adults occurred at 475 degree-days in 1997, or about two warm days earlier than the 519 degree-days in 1998. If we average the two years, we conclude that bronze birch borer emergence occurs at approximately 496 degree-days (when we specify a base temperature of 50°F and a starting date of January 1). After data have been collected over three or four years, this method becomes quite accurate for many insects.

Since the lower developmental threshold temperature is only known for a few plants and animals, 50°F is often used as the base

Table 1. Daily Degree-Day Accumulation Calculated Using the Modified Sine Wave Method When the Minimum Temperature Falls Below a Base Temperature of 50°F.

Maximum Temperature	Minimum Temperature						
	20	25	30	35	40	45	50
50	0	0	0	0	0	0	0
55	0	1	1	1	1	1	1
60	2	2	2	2	2	3	4
65	3	3	4	4	4	5	6
70	5	5	5	6	6	7	9
75	7	7	7	8	9	10	11
80	9	9	10	10	11	12	14
85	11	11	12	13	13	15	16
90	13	13	14	15	16	17	19
95	15	16	16	17	18	19	21
100	17	18	19	20	21	22	24

temperature (which has proven to be a good approximation for many species). If the lower threshold temperature varies substantially from the selected base temperature, then large differences will occur from year-to-year in the number of degree-days required for a particular event such as insect emergence.

Furthermore, January 1 may not be the best starting-date to begin accumulating degree-days. The overwintering stage of many insects does not undergo development until it has been exposed to a cold period. For these species, January 1 is a safe starting-date. However, in some species, the overwintering stage can also undergo significant development in the late summer and fall. In this case, a starting-date from the previous summer or fall will be more accurate.

Highly accurate models can be constructed by evaluating different starting dates and base temperatures over several years to determine the best combination. For example, a three-year study found that adult emergence of bronze birch borer was most accurately predicted in Columbus, Ohio, using a starting date of May 1 and a base temperature of 46°F (Akers and Nielsen, 1984).

There are a number of even more sophisticated methods for modeling insect phenology. However, because of the limitations described in this report, these models are often no more accurate than the simpler methods when applied in the field.

Limitations of Degree-Day Models

By far, the greatest source of error in degree-day models originates in the temperature data used to calculate degree-days. It is virtually impossible to measure the tem-

Table 2. Steps to Follow in the Construction of a Degree-Day Model.

1. Identify and monitor a phenological (e.g., flowering, egg hatch) event of a plant and / or pest.

2. Determine an appropriate base temperature. If the lower developmental threshold is not known for the species being monitored, use 50°F.

3. Select a starting date for degree-day accumulation (January 1 in most cases).

4. Record daily maximum and minimum temperatures for your locale (or obtain them from the nearest weather station).

5. From the maximum and minimum temperature, calculate the number of degree-days that accumulate each day.

    5a. If the minimum temperature does not fall below the base temperature, use the Average Method.

    5b. If the minimum temperature does fall below the base temperature, use the Modified Sine Wave method (degree-day values using this method can be obtained from Table 1).

6. When the phenological event that is being monitored occurs, note the total number of degree-days that have accumulated since the starting date.

7. Use this value to predict the occurrence of the phenological event in future years.

perature that insects actually experience. Micro-environments in which insects exist are generally very different from the environment of the thermometer used to collect the temperature data. Furthermore, many insects exert some control over their body temperatures through their behavior. For example, they will move to dark surfaces in the sun when they are too cool and to light surfaces in the shade when they are too warm.

Researchers can develop highly accurate models by recording temperatures directly in the insect's environment (for example, by affixing a microprobe directly to the insect). However, these temperatures will differ so dramatically from ambient that such models will be of little value when used with data collected from weather stations. For this reason, practical models are developed from temperature data collected from the same standardized sources that growers and other users of the model also have access to, such as weather stations. Experience has shown that over several years, errors in estimating insect development using standardized data tend to cancel themselves out, leading to models that are accurate enough for practical purposes. For his models, the author uses daily maximum and minimum temperature data from The

Ohio State University's Ohio Agricultural Research and Development Center (OARDC) Weather System. Data from this system are available for a number of locations throughout Ohio and can be accessed via the World Wide Web at:

http://www.oardc.ohio-state.edu/weather

There are other sources of error in degree-day models, but they are usually relatively small. For example, the methods used to calculate degree-days assume that the development rates of insects are a linear function of temperature. However, temperature has nonlinear effects, especially as temperatures approach the upper and lower threshold (Figure 1). When the temperature oscillates around the base temperature for long periods of time, as it sometimes does in cool springs, errors in prediction can become fairly substantial.

Degree-day models also assume that development rate is only a function of temperature. However, other factors have important effects on development time — for example, the quality of host plants for insects and drought stress for plants. The variation that these factors contribute to developmental time are difficult to quantify and are generally not incorporated in degree-day models.

Conclusions

Despite these limitations in using degree-day models for predicting insect and plant development, these models have great practical value when used in the field. Degree-day models are much more accurate than calendar-based schedules for timing horticultural pest-management practices. Useful degree-day models can be constructed by observing plant and insect activity and then calculating cumulative degree-days using the Average Method (or Table 1, when the minimum temperature falls below the base temperature). Experience has shown that for practical application in the field, this method is just as useful as more complex models.

An alternative approach is to let plants do the work for you. Because both plant and insect development is temperature dependent, plants track the same environmental variables that affect insect development. As a result, plant phenological events such as flowering time can be used to predict insect activity. The next report discusses how the sequence of blooming times of plants can be used to track degree-day accumulation and predict insect emergence.

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Plant and Insect Phenology in the Year of El Niño: Comparison with 1997

Daniel A. Herms

Summary

Since the development of both insects and plants is temperature dependent, plants may accurately track the environmental factors that affect insect development. If a sequence of plant phenological events, such as flowering time, can be shown to correspond with the appearance of insect pests, pest managers could use the easily monitored plant sequence to predict the order and the time pests reach vulnerable stages, greatly simplifying the logistics required to effectively manage the large number of pests infesting the great diversity of ornamental plants.

This report presents the phenological sequence of 82 plant and 40 insect and mite taxa for Wooster, Ohio, in 1998. Degree-day data for all phenological events in the sequence are also presented. The fundamental assumption behind the use of phenological indicators for predicting pest activity is that phenological events occur in the same (or nearly the same) order from one year to the next. The phenological sequence for 1998 was found to be very similar to the 1997 sequence, even though patterns of degree-day accumulation varied dramatically between 1997 (cool spring) and 1998 (warm spring). In general, plant phenology in 1998 was predicted more accurately than insect phenology by the 1997 sequence, although the phenology of most insects was predicted quite accurately. The phenology of all insects was predicted more accurately by plant phenology than by calendar days.

Introduction

Difficulties in detecting and monitoring the tremendous diversity of insect pests of ornamental plants makes accurate timing of pesticide applications and other pest-management tactics challenging. Consequently, pesticide applications frequently are scheduled on a calendar-day basis. However, variation in patterns of degree-day accumulation from one year to the next frequently makes calendar-based scheduling inaccurate.

The use of plant phenology provides an alternative approach for predicting insect activity.

Phenology is the study of recurring biological phenomena such as the blooming of plants and the seasonal appearance of insects. Because plant and insect phenology are both temperature-dependent, it may be possible to use plant phenology to accurately predict insect appearance. If a sequence of plant phenological events, such as flowering time, can be shown to correspond with the appearance of insect pests, pest managers could use the easily monitored

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plant sequence as a biological clock to anticipate the order and time pests reach vulnerable stages. This would greatly facilitate the logistics of serving many clients with a variety of pest problems.

The critical assumption underlying the accurate use of phenological indicators for predicting pest activity is the existence of a high level of consistency in the sequence from region to region. In recent years, several studies have been published that permit scrutiny of this assumption, including an extensive list of observations made in Illinois (Orton and Green, 1989) and phenological sequences from three regions that were developed using the same protocols — Midland, Michigan (Herms, 1990); Lexington, Kentucky (Mussey and Potter, 1997); and Wooster, Ohio (Herms, 1998). An analysis of the Michigan and the Ohio sequences revealed that reliance on the Michigan sequence for timing pesticide applications in Ohio in 1997 would have been effective for many but not all pests (Herms, 1998). There are a number of reasons why discrepancies may occur in phenological sequences from region to region, some of which the author has discussed previously (Herms 1990, 1998).

Another critical assumption is that phenological patterns will remain constant from year-to-year in the same region when weather patterns differ greatly. A comparison of 1997 and 1998 provides an ideal opportunity for testing this assumption; 1997 was characterized by a delayed, cool spring, while 1998, the year of El Niño, was characterized by an early, warm spring.

The objectives of this report are to:

- Report the phenological sequence for Wooster, Ohio, for 1998.
- Present degree-day data for plant and insect phenological events in 1998.
- Compare patterns of degree-day accumulation in 1997 and 1998.
- Compare the 1998 Wooster sequences with that of 1997.

Methods and Materials

During 1997, the phenology of 56 plant species and/or cultivars and 22 species of insects on or near the campus of The Ohio State University's Ohio Agricultural Research and Development Center (OARDC) in Wooster, Ohio, were monitored. In 1998 this list was expanded to 86 plant and 36 insect taxa. (See Table 1). For clarity, only common names are listed. To achieve standardization in nomenclature, common names of plants follow Dirr (1983), and insect names are official common names as approved by the Entomological Society of America.

Plants were chosen to represent a range of blooming times from early March through late July. This time period corresponds with the activity of most of the important insect pests of ornamental plants. Four individuals of each species or cultivar were monitored. All individuals of a species were located either in uniform sun or shade, depending on the environment to which the species is adapted. Plants in microenvironments obviously altered by buildings, parking lots, and other factors were not used.

Plants were monitored at least three times each week, and the dates of "first bloom" and "full bloom" were recorded. "First bloom" is defined as the date on which the first flower bud on the plant opens, revealing pistils and/or stamens. "Full bloom" is defined as the date on which 95% of the flower buds have opened (i.e., one bud out of 20 has yet to open). These phenological events can be identified and recorded with precision.

The phenology of 40 insect and mite species with diverse life histories was also monitored in 1998, including defoliators, scales,

(Text continues on page 83.)

Table 1. Phenological Sequence for Wooster, Ohio, in 1998. (Insect names are indicated in bold.)

Species	Phenological Event	Date	Degree-Day Base 50
Silver Maple	first bloom	Feb 25	24
Corneliancherry Dogwood	first bloom	Mar 10	32
Silver Maple	full bloom	Mar 15	32
Red Maple	first bloom	Mar 23	36
Forsythia x 'Northern Lights'	first bloom	Mar 25	37
Japanese Andromeda	first bloom	Mar 25	37
Speckled Alder	first bloom	Mar 27	63
Border Forsythia	first bloom	Mar 28	80
Eastern Tent Caterpillar	**egg hatch**	**Mar 28**	**80**
Corneliancherry Dogwood	full bloom	Mar 28	80
Red Maple	full bloom	Mar 28	80
Star Magnolia	first bloom	Mar 28	80
Manchu Cherry	first bloom	Mar 28	80
Forsythia x 'Northern Lights'	full bloom	Mar 29	94
Japanese Andromeda	full bloom	Mar 29	94
Chanticleer Callery Pear	first bloom	Mar 30	114
Norway Maple	first bloom	Mar 30	114
Border Forsythia	full bloom	Mar 30	114
Sargent Cherry	first bloom	Mar 31	132
Speckled Alder	full bloom	Mar 31	132
Norway Maple	full bloom	Mar 31	132
Bradford Callery Pear	first bloom	Apr 1	144
Weeping Higan Cherry	first bloom	Apr 1	144
Rhododendron 'PJM'	first bloom	Apr 1	144
Common Floweringquince	first bloom	Apr 1	144
Sargent Cherry	full bloom	Apr 1	144
Chanticleer Callery Pear	full bloom	Apr 1	144
Manchu Cherry	full bloom	Apr 2	149
European Pine Sawfly	**egg hatch**	**Apr 6**	**152**
Larch Casebearer	**egg hatch**	**Apr 6**	**152**
Spring Snow Crabapple	first bloom	Apr 6	152
Allegheny Serviceberry	first bloom	Apr 7	155
Bradford Callery Pear	full bloom	Apr 7	155
Apple Serviceberry	first bloom	Apr 8	163
Saucer Magnolia	first bloom	Apr 8	163
PJM Rhododendron	full bloom	Apr 8	169
Spiraea x *arguta* 'Compacta'	first bloom	Apr 8	163
Allegheny Serviceberry	full bloom	Apr 9	169
Inkberry Leafminer	**adult emergence**	**Apr 10**	**171**
Weeping Higan Cherry	full bloom	Apr 11	172
Apple Serviceberry	full bloom	Apr 11	172
Amelanchier 'Regent'	first bloom	Apr 13	183
Koreanspice Viburnum	first bloom	Apr 13	183
Common Floweringquince	full bloom	Apr 13	183
Japanese Flowering Crabapple	first bloom	Apr 14	192
Eastern Redbud	first bloom	Apr 14	192
Boxwood Psyllid	**egg hatch**	**Apr 15**	**198**

Table 1 (cont.). Phenological Sequence for Wooster, Ohio, in 1998. (Insect names are indicated in bold.)

Species	Phenological Event	Date	Degree-Day Base 50
Common Chokecherry	first bloom	Apr 16	208
Gypsy Moth	**egg hatch**	**Apr 16**	**208**
Spiraea x *arguta* 'Compacta'	full bloom	Apr 16	208
Donald Wyman Crabapple	first bloom	Apr 16	208
Snowdrift Crabapple	first bloom	Apr 17	214
Spring Snow Crabapple	full bloom	Apr 17	214
Koreanspice Viburnum	full bloom	Apr 17	214
Carolina Silverbell	first bloom	Apr 18	216
Coral Burst Crabapple	first bloom	Apr 18	216
Spruce Spider Mite	**egg hatch**	**Apr 20**	**219**
Amelanchier 'Regent'	full bloom	Apr 21	224
Common Chokecherry	full bloom	Apr 21	224
Birch Leafminer	**adult emergence**	**Apr 22**	**231**
Elm Leafminer	**adult emergence**	**Apr 22**	**231**
Hawthorn Lace Bug	**adult emergence**	**Apr 22**	**231**
Honeylocust Plant Bug	**egg hatch**	**Apr 22**	**231**
Wayfaringtree Viburnum	first bloom	Apr 22	231
Persian Lilac	first bloom	Apr 23	238
Tatarian Honeysuckle	first bloom	Apr 23	238
Common Lilac	first bloom	Apr 23	238
Japanese Flowering Crabapple	full bloom	Apr 23	238
Snowdrift Crabappl	full bloom	Apr 24	244
Imported Willow Leaf Beetle	**adult emergence**	**Apr 24**	**244**
Sargent Crabapple	first bloom	Apr 24	244
Alder Leafminer	adult emergence	Apr 25	251
Flowering Dogwood	first bloom	Apr 26	255
Donald Wyman Crabapple	full bloom	Apr 26	256
Ohio Buckeye	first bloom	Apr 26	256
Common Horsechestnut	first bloom	Apr 27	257
Eastern Redbud	full bloom	Apr 27	257
Coral Burst Crabapple	full bloom	Apr 29	264
Red Chokeberry	first bloom	Apr 29	264
Blackhaw Viburnum	first bloom	Apr 29	264
Red Buckeye	first bloom	Apr 30	274
Carolina Silverbell	full bloom	Apr 30	274
Wayfaringtree Viburnum	full bloom	May 1	284
Pink Princess Weigela	first bloom	May 1	284
Sargent Crabapple	full bloom	May 2	292
Red Horsechestnut	first bloom	May 2	292
Eastern Spruce Gall Adelgid	**egg hatch**	**May 3**	**301**
Pine Needle Scale	**egg hatch — 1st generation**	**May 3**	**301**
Common Lilac	full bloom	May 3	301
Persian Lilac	full bloom	May 4	312
Bigleaf Magnolia	first bloom	May 4	312
Vanhoutte Spirea	first bloom	May 4	312
Blackhaw Viburnum	full bloom	May 4	312
Lilac Borer	**adult emergence**	**May 5**	**322**

Table 1 (cont.). Phenological Sequence for Wooster, Ohio, in 1998. (Insect names are indicated in bold.)

Species	Phenological Event	Date	Degree-Day Base 50
Redosier Dogwood	first bloom	May 5	322
Common Horsechestnut	full bloom	May 5	322
Red Java Weigela	first bloom	May 6	333
Slender Deutzia	first bloom	May 6	333
Winter King Hawthorn	first bloom	May 6	333
Ohio Pioneer Thicket Hawthorn	first bloom	May 6	333
Lesser Peach Tree Borer	**adult emergence**	**May 6**	**333**
Doublefile Viburnum	first bloom	May 7	348
Pagoda Dogwood	first bloom	May 7	347
Red Chokeberry	full bloom	May 8	362
Ohio Buckeye	full bloom	May 8	362
Holly Leafminer	**adult emergence**	**May 9**	**376**
Black Cherry	first bloom	May 9	376
Catawba Rhododendron	first bloom	May 9	376
Scarlet Firethorn	first bloom	May 10	387
Winter King Hawthorn	full bloom	May 11	397
Ohio Pioneer Thicket Hawthorn	full bloom	May 11	397
Beautybush	first bloom	May 11	397
Tatarian Honeysuckle	full bloom	May 12	407
Vanhoutte Spirea	full bloom	May 12	407
Black Cherry	full bloom	May 13	420
Red Horsechestnut	full bloom	May 13	420
Bush Cinquefoil	first bloom	May 14	439
White Fringetree	first bloom	May 14	439
Redosier Dogwood	full bloom	May 15	463
Euonymus Scale	**egg hatch — 1st generation**	**May 15**	**463**
Red Prince Weigela	first bloom	May 15	463
Pagoda Dogwood	full bloom	May 15	463
Doublefile Viburnum	full bloom	May 15	463
Catawba Rhododendron	full bloom	May 15	463
Snowmound Nippon Spirea	first bloom	May 16	486
Common Ninebark	first bloom	May 16	486
Pink Princess Weigela	full bloom	May 16	486
Black Locust	first bloom	May 17	503
Oystershell Scale	**egg hatch**	**May 17**	**502**
Tiger Swallowtail Butterfly	**first adult**	**May 17**	**502**
Red Buckeye	full bloom	May 17	503
Red Java Weigela	full bloom	May 17	503
Sweet Mockorange	first bloom	May 17	503
White Fringetree	full bloom	May 17	503
Bigleaf Magnolia	full bloom	May 18	519
Scarlet Firethorn	full bloom	May 18	519
Bronze Birch Borer	**adult emergence**	**May 18**	**519**
Arrowwood Viburnum	first bloom	May 18	519
Multiflora Rose	first bloom	May 18	519
Beautybush	full bloom	May 19	539
Smokebush	first bloom	May 19	519
American Holly	first bloom	May 20	565

Table 1 (cont.). Phenological Sequence for Wooster, Ohio, in 1998. (Insect names are indicated in bold.)

Species	Phenological Event	Date	Degree-Day Base 50
Mountain-laurel	first bloom	May 20	565
Snowmound Nippon Spirea	full bloom	May 20	565
Black Locust	full bloom	May 21	579
Common Ninebark	full bloom	May 21	579
Juniper Scale	**egg hatch**	**May 21**	**579**
Potato Leafhopper	**adult arrival**	**May 22**	**588**
Smokebush	full bloom	May 22	588
Sweetbay Magnolia	first bloom	May 23	599
American Yellowwood	first bloom	May 23	599
Chinese Dogwood	first bloom	May 23	599
Japanese Tree Lilac	first bloom	May 23	599
Multiflora Rose	full bloom	May 24	610
Arrowwood Viburnum	full bloom	May 24	610
Red Prince Weigela	full bloom	May 25	622
American Holly	full bloom	May 26	634
Washington Hawthorn	first bloom	May 26	634
American Yellowwood	full bloom	May 26	634
Monarch Butterfly	**first adult**	**May 27**	**648**
Bumald Spirea	first bloom	May 27	648
Northern Catalpa	first bloom	May 28	665
American Elder	first bloom	May 28	665
Sweet Mockorange	full bloom	May 29	690
Calico Scale	**egg hatch**	**May 30**	**713**
Washington Hawthorn	full bloom	May 31	734
Lightning Bug	**first flash**	**May 31**	**734**
Dogwood Borer	**adult emergence**	**May 31**	**734**
Black Vine Weevil	**adult emergence**	**May 31**	**734**
European Fruit Lecanium Scale	**egg hatch**	**Jun 1**	**749**
Winterberry Holly	first bloom	Jun 3	777
Japanese Tree Lilac	full bloom	Jun 4	784
Pine Tortoise Scale	**egg hatch**	**Jun 4**	**784**
Northern Catalpa	full bloom	Jun 6	792
Rhododendron Borer	**adult emergence**	**Jun 6**	**792**
Mountain-laurel	full bloom	Jun 8	802
Oakleaf Hydrangea	first bloom	Jun 9	811
Spruce Budscale	**egg hatch**	**Jun 12**	**860**
Peach Tree Borer	**adult emergence**	**Jun 12**	**860**
Fall Webworm	**egg hatch**	**Jun 12**	**860**
Mimosa Webworm	**first larvae**	**Jun 12**	**860**
Winged Euonymus Scale	**egg hatch**	**Jun 12**	**860**
Greenspire Littleleaf Linden	first bloom	Jun 12	860
American Elder	full bloom	Jun 12	860
Winterberry Holly	full bloom	Jun 13	880
Southern Catalpa	first bloom	Jun 14	897
Cottony Maple Scale	**egg hatch**	**Jun 14**	**897**
Panicled Goldenraintree	first bloom	Jun 15	915
Rosebay Rhododendron	first bloom	Jun 17	955

Table 1 (cont.). Phenological Sequence for Wooster, Ohio, in 1998. (Insect names are indicated in bold.)

Species	Phenological Event	Date	Degree-Day Base 50
Azalea Bark Scale	**egg hatch**	**Jun 17**	**955**
Japanese Beetle	**adult emergence**	**Jun 17**	**955**
Bumald Spirea	full bloom	Jun 19	1003
Bottlebrush Buckeye	first bloom	Jun 23	1105
Southern Catalpa	full bloom	Jun 23	1105
Greenspire Littleleaf Linden	full bloom	Jun 23	1105
Panicled Goldenraintree	full bloom	Jun 23	1105
Rosebay Rhododendron	full bloom	Jun 29	1273
Pine Needle Scale	**egg hatch — 2nd generation**	**Jun 30**	**1292**
Bottlebrush Buckeye	full bloom	Jul 6	1410
Mimosa Webworm	**egg hatch — 2nd generation**	**Jul 29**	**1920**
Euonymus Scale	**egg hatch — 2nd generation**	**Jul 30**	**1939**
Magnolia Scale	**crawler appearance**	**Aug 7**	**2120**

(Continued from page 78)

gall formers, wood borers, leafminers, and butterflies. As opposed to methods used to monitor plant phenology, which were designed to minimize variation in order to increase predictive power, sampling protocols for insects were designed to characterize the phenology of the entire population.

Degree-days for 1997 and 1998 were calculated using the double sine wave method (Allen, 1976) from daily maximum and minimum temperature data for Wooster (OARDC Weather System, Wooster Station) and a base temperature of 50°F and a starting date of January 1.

Results and Discussion

The Phenological Sequence

The phenological sequence observed in Wooster, Ohio, in 1998 is presented in Table 1. A comparison of plant and insect phenology in 1997 and 1998 is presented in Table 2. In general, plant and insect phenology was substantially accelerated in 1998 relative to 1997. A comparison of degree-day accumulation in 1997 and 1998 confirms that 1998 was warmer (almost 3,200 degree-days had accumulated by October 1 in 1998, compared with 2,500 in 1997). (See Figure 1.) However, a couple of patterns are worth noting.

The winter of 1997–98 was among the mildest in recorded history, yet more degree-days accumulated prior to March 26 in 1997 than in 1998 (Figure 1, inset), and several plant species actually bloomed at about the same time in both years (e.g., corneliancherry dogwood, red maple, forsythia). To understand this apparent paradox, it is important to realize that degree-days are calculated above a lower threshold temperature, in this case 50°F (below which many insects and plants do not develop). So it does not matter if the high temperature for the day is 48°F or 0°F; in both cases there is no degree-day accumulation. However, when 32°F is used for

(Text continues on page 86.)

Table 2. Comparison of the Phenological Sequence for Wooster, Ohio, in 1998 With That of 1997. (Insect names are indicated in bold.)

Species	Phenological Event	Date of Occurrence in 1998	Date of Occurrence in 1997	Order of Occurrence in 1998	Order of Occurrence in 1997	Disparity in Order of Occurrence
Silver Maple	first bloom	Feb 25	Mar 7	1	1	0
Corneliancherry Dogwood	first bloom	Mar 10	Mar 15	2	2	0
Red Maple	first bloom	Mar 23	Mar 25	3	3	0
Forsythia x 'Northern Lights'	first bloom	Mar 25	Mar 30	4	4	0
Border Forsythia	first bloom	Mar 28	Mar 30	5	5	0
Eastern tent caterpillar	**egg hatch**	**Mar 28**	**Apr 4**	**6**	**7**	**-1**
Manchu Cherry	first bloom	Mar 28	Apr 2	7	6	1
Star Magnolia	first bloom	Mar 28	Apr 4	8	8	0
Chanticleer Callery Pear	first bloom	Mar 30-	Apr 7	9	11	-2
Norway Maple	first bloom	Mar 30	Apr 6	10	10	0
Sargent Cherry	first bloom	Mar 31	Apr 5	11	9	2
Weeping Higan Cherry	first bloom	Apr 1	Apr 20	12	15	-3
Bradford Callery Pear	first bloom	Apr 1	Apr 21	13	16	-3
PJM Rhododendron	first bloom	Apr 1	Apr 21	14	17	-3
Common Floweringquince	first bloom	Apr 1	Apr 23	15	20	-5
European pine sawfly	**egg hatch**	**Apr 6**	**Apr 15**	**12**	**4**	
Larch casebearer	**egg hatch**	Apr 6	**Apr 15**	**17**	**13**	**4**
Spring Snow Crabapple	first bloom	Apr 6	Apr 22	18	18	0
Allegheny Serviceberry	first bloom	Apr 7	Apr 23	19	21	-2
Apple Serviceberry	first bloom	Apr 8	Apr 22	20	19	1
Spiraea x *arguta* 'Compacta'	first bloom	Apr 8	Apr 27	21	23	-2
Inkberry leafminer	**adult emergence**	**Apr 10**	**Apr 15**	**22**	**14**	**8**
Amelanchier 'Regent'	first bloom	Apr 13	May 1	23	24	-1
Koreanspice Viburnum	first bloom	Apr 13	Apr 26	24	22	2
Japanese Flowering Crab	first bloom	Apr 14	May 5	25	27	-2
Eastern Redbud	first bloom	Apr 14	May 7	26	29	-3
Gypsy moth	**egg hatch**	**Apr 16**	**May 7**	**27**	**30**	**-3**
Donald Wyman Crabapple	first bloom	Apr 16	May 4	28	26	2
Snowdrift Crabapple	first bloom	Apr 17	May 2	29	25	4
Coral Burst Crabapple	first bloom	Apr 18	May 11	30	33	-3
Birch leafminer	**adult emergence**	**Apr 22**	**May 5**	**31**	**28**	**3**
Honeylocust plant bug	**egg hatch**	**Apr 22**	**May 16**	**32**	**37**	**-5**
Wayfaringtree Viburnum	first bloom	Apr 22	May 10	33	31	2
Tatarian Honeysuckle	first bloom	Apr 23	May 12	34	34	0
Common Lilac	first bloom	Apr 23	May 15	35	36	-1
Imported willow leaf beetle	**adult emergence**	**Apr 24**	**May 18**	**36**	**38**	**-2**
Sargent Crabapple	first bloom	Apr 24	May 10	37	32	5
Ohio Buckeye	first bloom	Apr 26	May 14	38	35	3
Red Chokeberry	first bloom	Apr 29	May 19	39	40	-1
Blackhaw Viburnum	first bloom	Apr 29	May 19	40	41	-1
Red Buckeye	first bloom	Apr 30	May 18	41	39	2
Pink Princess Weigela	first bloom	May 1	May 20	42	43	-1
Red Horsechestnut	first bloom	May 2	May 19	43	42	1
Eastern spruce gall adelgid	**egg hatch**	**May 3**	**May 22**	**44**	**44**	**0**

Table 2 (continued). Comparison of the Phenological Sequence for Wooster, Ohio, in 1998 With That of 1997. (Insect names are indicated in bold.)

Species	Phenological Event	Date of Occurrence in 1998	Date of Occurrence in 1997	Order of Occurrence in 1998	Order of Occurrence in 1997	Disparity in Order of Occurrence
Pine needle scale	**egg hatch**	**May 3**	**May 22**	**45**	**45**	**0**
Bigleaf Magnolia	first bloom	May 4	May 26	46	47	-1
Vanhoutte Spirea	first bloom	May 4	May 25	47	46	1
Lilac borer	**adult emergence**	**May 5**	**May 30**	**48**	**55**	**-7**
Redosier Dogwood	first bloom	May 5	May 27	49	51	-2
Winter King Hawthorn	first bloom	May 6	May 26	50	48	2
Ohio Pioneer Hawthorn	first bloom	May 6	May 26	51	49	2
Slender Deutzia	first bloom	May 6	May 29	52	53	-1
Lesser peach tree borer	**adult emergence**	**May 6**	**Jun 4**	**53**	**61**	**-8**
Doublefile Viburnum	first bloom	May 7	Jun 27	54	50	4
Pagoda Dogwood	first bloom	May 7	Jun 30	55	56	-1
Holly leafminer	**adult emergence**	**May 9**	**Jun 29**	**56**	**54**	**2**
Black Cherry	first bloom	May 9	Jun 28	57	52	5
Scarlet Firethorn	first bloom	May 10	Jun 1	58	58	0
Beautybush	first bloom	May 11	Jun 3	59	61	-2
Bush Cinquefoil	first bloom	May 14	Jun 8	60	62	-2
White Fringetree	first bloom	May 14	Jun 9	61	64	-3
Euonymus scale	**egg hatch**	**May 15**	**May 30**	**62**	**57**	**5**
Red Prince Weigela	first bloom	May 15	Jun 3	63	60	3
Common Ninebark	first bloom	May 16	Jun 9	64	65	-1
Black Locust	first bloom	May 17	Jun 9	65	66	-1
Oystershell scale	**egg hatch**	**May 17**	**Jun 9**	**66**	**67**	**-1**
Sweet Mockorange	first bloom	May 17	Jun 8	67	63	4
Bronze birch borer	**adult emergence**	**May 18**	**Jun 12**	**68**	**68**	**0**
Arrowwood Viburnum	first bloom	May 18	Jun 12	69	69	0
Smokebush	first bloom	May 19	Jun 12	70	70	0
American Holly	first bloom	May 20	Jun 13	71	72	-1
Mountain-laurel	first bloom	May 20	Jun 12	72	71	1
Juniper scale	**egg hatch**	**May 21**	**Jun 14**	**73**	**74**	**-1**
Potato leafhopper	**adult arrival**	**May 22**	**Jun 16**	**74**	**75**	**-1**
Sweetbay Magnolia	first bloom	May 23	Jun 22	75	78	-3
Japanese Tree Lilac	first bloom	May 23	Jun 21	76	77	-1
Washington Hawthorn	first bloom	May 26	Jun 20	77	76	1
Bumald Spirea	first bloom	May 27	Jun 14	78	73	5
Northern Catalpa	first bloom	May 28	Jun 22	79	79	0
American Elder	first bloom	May 28	Jun 22	80	80	0
Fall Webworm	**egg hatch**	**Jun 12**	**Jun 24**	**81**	**81**	**0**
Spruce budscale	**egg hatch**	**Jun 12**	**Jun 30**	**82**	**82**	**0**
Peach tree borer	**adult emergence**	**Jun 12**	**Jul 8**	**83**	**87**	**-4**
Greenspire Littleleaf Linden	first bloom	Jun 12	Jun 30	84	83	1
Panicled Goldenraintree	first bloom	Jun 15	Jul 7	85	85	0
Japanese beetle	**adult emergence**	**Jun 17**	**Jul 2**	**86**	**84**	**2**
Rosebay Rhododendron	first bloom	Jun 17	Jul 7	87	86	1
Magnolia scale	**egg hatch**	**Aug 7**	**Aug 3**	**88**	**88**	**0**

the lower threshold, it is apparent that the winter of 1998 was warmer; 397 degree-days accumulated by March 1 in 1998 compared with 298 in 1997.

The warm spring of 1998 began in earnest in late March. Between March 26 and March 31 the high temperature in Wooster reached at least 75°F every day. This warm spell catapulted 1998 degree-day accumulation and plant phenology well beyond that of 1997 (Table 2, Figure 1). For example, Bradford Callery Pear began blooming on April 1 in 1998, but not until April 21 in 1997. Degree-day accumulation between mid-May and mid-August was very similar during 1997 and 1998. However, because of the warmer weather during the early part of the spring of 1998, plant and insect phenology remained about three weeks ahead of 1997 throughout the growing season.

Despite the dramatic differences in the springs of 1997 and 1998, the phenological

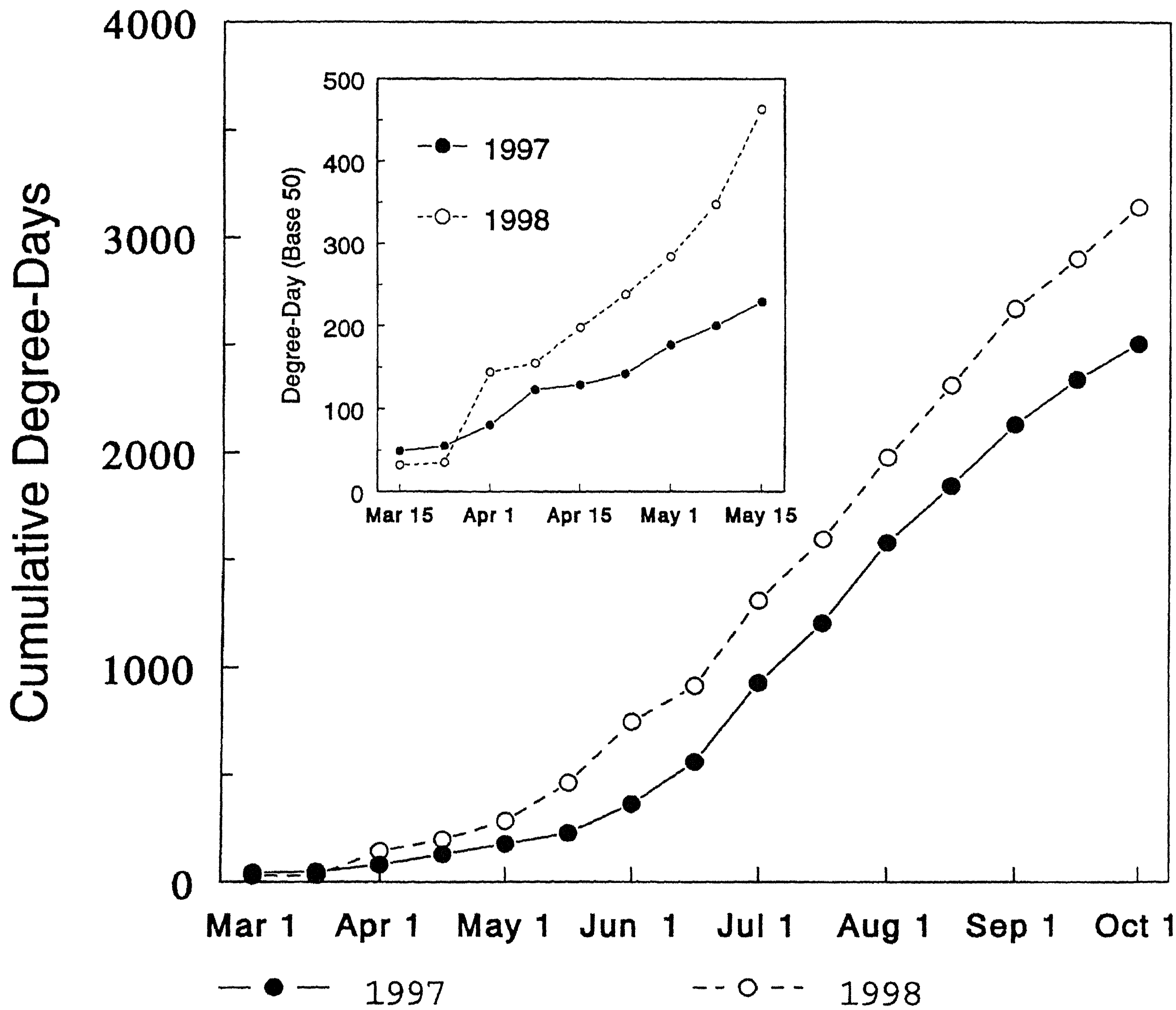

Figure 1. Comparison of patterns of degree-day accumulation in Wooster, Ohio, in 1997 and 1998. Inset figure provides fine-scale resolution between March 15 and May 15.

sequence was, for the most part, quite consistent during the two years. In Table 2, the order in which phenological events occurred in 1998 is compared with the order in which they occurred in 1997. The magnitude of any disparity in the order in which a particular event occurred in the two sequences is also shown. A positive value indicates that the event occurred earlier in the sequence in 1997, while a negative value indicates that the event occurred earlier in 1998.

The correspondence in the flowering sequences of the plants common to both studies was quite close. Flowering of silver maple occurred first during both years, followed by flowering of corneliancherry dogwood, red maple, 'Northern Lights' forsythia, border forsythia, manchu cherry, and star magnolia. In fact, in no case did the order of flowering by any species vary by more than the five places between the two years, and only common flowering-quince, sargent crabapple (which bloomed very lightly in 1998), and bumald spirea varied by five places (Table 2). As more plant species are included in the sequence, the chance that one will be led astray by any one species that departs from the pattern will diminish.

In general, the sequence of insect phenological events also corresponded closely between the two years. For example, the phenology of eastern tent caterpillar, eastern spruce gall adelgid, pine needle scale, oystershell scale, bronze birch borer, juniper scale, potato leafhopper, fall webworm, spruce budscale, and magnolia scale were all predicted with great accuracy. None of these species deviated by more than one position in the sequence between the two years.

The phenology of other insect species did not correspond as closely. Inkberry leafminer, lilac borer, and lesser peach tree borer deviated by more than five places in the sequence. A number of factors may affect the accuracy of plant phenological indicators as predictors of insect activity. The assumption that a given phenological correlation will occur from one year to the next requires that all organisms included in the correlation have the same upper and lower temperature thresholds for development, as well as the same developmental responses to changing temperature. These traits are known to vary widely among both plants and insects (Tauber and Tauber, 1981; Rathke and Lacey, 1985).

When temperatures differ widely among years, as they did in 1997 and 1998, then variation in these traits will cause discrepancies in the phenological sequence, especially if temperatures frequently drop below or hover near the lower threshold of 50°F, as they did during the spring of 1997. However, the phenology of all insects was predicted more accurately by plant phenology than by the calendar, and the use of plant phenological indicators for timing pest activity holds tremendous potential for improving the effectiveness of integrated pest management programs in the landscape.

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Evaluation of Crabapples for Apple Scab at the Secrest Arboretum in Wooster, Ohio: 1998

Erik A. Draper, James A. Chatfield, Kenneth C. Cochran, Peter W. Bristol, and Charles F. Tubesing

Summary

Crabapples in a replicated plot at the Secrest Arboretum of The Ohio State University's Ohio Agricultural Research and Development Center were evaluated for apple scab three times in 1998. Seventeen of the selections had no scab at any of the three ratings in 1998. Fourteen of the selections had scab that resulted in significant negative effect on aesthetics on at least one of the ratings.

Fifteen of the crabapples were removed from the plot in 1998 due to poor overall aesthetics over the past five years, and the summaries of scab ratings for these crabapples are reported. Scab ratings for the past six years are reported for the remaining 27 selections, and ratings for 14 newer plantings are averaged for the past two years.

Other diseases noted included bacterial fireblight, frogeye leaf spot, sooty blotch, and flyspeck.

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Introduction

Apple scab (pathogen: *Venturia inaequalis)* is a major fungal disease problem of many crabapple species *(Malus* spp). Although it generally is not a major health problem for the tree, it can severely impact ornamental effect and the marketability of highly susceptible crabapples.

Symptoms of apple scab on crabapple include olive to gray to brown to black spots on foliage, yellowing and discoloration of foliage, leaf drop, and scabby lesions on fruits. Apple scab can be effectively controlled with a fungicide spray program, and certain cultural and sanitary practices (thinning to avoid dense canopies, cleanup of leaves at the end of the season) are also beneficial for control.

However, the best method for control of apple scab is through the use of genetically resistant crabapple selections. The evaluations presented here are the latest in a series of apple scab evaluations for Ohio (1–3).

The authors emphasize that apple scab in particular and diseases and pests in general are not the only consideration relative to crabapple effectiveness in the landscape. This is the rationale for the inception of more comprehensive evaluations of a number of different aesthetic criteria. These include fruit, flower, and foliage features; plant texture and shape; and disease and pest problems. These are reported in a series of publications from data collected in the

Secrest plot (4–7). The comprehensive crabapple evaluations at Secrest are a continuing project and are being expanded to include a second plot with additional selections.

Materials and Methods

Forty-one crabapples in the replicated crabapple plot at Secrest Arboretum were rated for apple scab disease on June 9, 1998; July 24, 1998; and August 20, 1998. This plot is in a completely randomized design with three replications of each crabapple selection (except for *M. zumi* 'Calocarpa,' with two surviving replicates). The plot was planted in 1984 and is not treated with fungicides or insecticides.

Apple scab evaluations were based on the following rating system:

0 = No scab noted.

1 = Slight scab; less than 5% of leaves affected; no negative effect on aesthetics.

2 = Moderate scab; 5%–20% of leaves affected; some yellowing; little or no defoliation; moderate negative effect on aesthetics.

3 = Extensive scab; 20%–50% of leaves affected; significant defoliation and/or leaf yellowing; significant negative effect on aesthetics.

4 = Heavy scab; 50%–80% of leaves affected; severe defoliation and discoloration of leaves; severe negative effect on aesthetics.

5 = Extreme scab; 80%–100% of foliage is affected, and defoliation is complete or nearly complete.

Scab on crabapple fruits was factored into the overall scab ratings.

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Table 1. Apple Scab Ratings for Crabapple Selections at Secrest Arboretum (6-9-98, 7-24-98, 8-20-98), and the Average Rating for Secrest Arboretum from 1993–1998.

Crabapple	Secrest 6-9-98	Secrest 7-24-98	Secrest 8-20-98	Secrest 1993-98
M. baccata 'Jackii'	0.0	0.0	0.0	0.0
'Beverly'	0.0	0.0	0.0	0.0
'Bob White'	0.0	0.0	0.0	0.0
'David'	1.0	1.0	1.0	0.9
'Dolgo'	0.0	0.0	0.0	0.0
'Donald Wyman'	2.0	2.0	3.0	1.3
M. floribunda	1.0	2.0	2.0	0.6
'Harvest Gold'	2.3	3.0	3.3	2.6
'Indian Magic'	2.0	2.6	3.0	2.7
'Indian Summer'	2.0	2.3	3.0	2.2
'Liset'	0.6	1.3	1.3	1.0
'Mary Potter'	0.3	1.0	1.0	0.6
'Molten Lava'	1.0	1.0	2.3	1.3
'Ormiston Roy'	0.0	0.3	0.6	0.3
'Prairifire'	0.0	0.0	0.0	0.0
'Professor Sprenger'	0.0	0.6	0.6	0.8
'Red Jade'	1.0	1.0	1.0	1.2
'Red Jewel'	0.0	0.3	0.3	0.1
'Red Splendor'	1.0	2.0	3.0	1.5
M. sargentii	0.0	0.0	0.0	0.0
'Sentinel'	0.0	1.0	1.0	0.7
'Silver Moon'	0.0	0.0	0.0	0.0
'Snowdrift'	1.0	2.0	3.0	2.2
'Strawberry Parfait'	0.0	0.0	0.0	0.1
'Sugar Tyme'	0.3	0.3	1.0	0.7
'White Angel'	0.0	0.0	0.0	0.0
'White Cascade'	1.6	3.0	3.0	2.2
M. zumi 'Calocarpa'	1.0	1.0	1.0	0.9

0 = No scab noted.
1 = Slight scab; less than 5% of leaves affected; no negative effect on aesthetics.
2 = Moderate scab; 50%–20% of leaves affected; some yellowing; little or no defoliation; moderate negative effect on aesthetics.
3 = Extensive scab; 20%–50% of leaves affected; significant defoliation and/or leaf yellowing; significant negative effect on aesthetics.
4 = Heavy scab; 50%–80% of leaves affected; severe defoliation and discoloration of leaves; severe negative effect on aesthetics.
5 = Extreme scab; 80%–100% of foliage is affected and defoliation is complete or nearly complete.

Scab on crabapple fruits was factored into the overall scab ratings.

Table 2. Apple Scab Ratings for Crabapple Selections at Secrest Arboretum from 1993-1997. These crabapples were discontinued in the plot due to poor overall aesthetic ratings.

Crabapple	1993–1997 Ratings
'Adams'	1.8
'Candied Apple'	1.8
'Centurion'	1.5
'Henningii'	2.0
M. Adstringens 'Hopa'	2.9
'Profusion'	2.8
'Radiant'	3.1
'Ralph Shay'	2.0
'Red Barron'	2.0
'Robinson'	2.5
'Royalty'	2.0
'Ruby Luster'	1.9
'Selkirk'	1.7
'Velvet Pillar'	2.8
'Winter Gold'	2.5

0 = No scab noted.
1 = Slight scab; less than 5% of leaves affected; no negative effect on aesthetics.
2 = Moderate scab; 50%–20% of leaves affected; some yellowing; little or no defoliation; moderate negative effect on aesthetics.
3 = Extensive scab; 20%–50% of leaves affected; significant defoliation and/or leaf yellowing; significant negative effect on aesthetics.
4 = Heavy scab; 50%–80% of leaves affected; severe defoliation and discoloration of leaves; severe negative effect on aesthetics.
5 = Extreme scab; 80%–100% of foliage is affected and defoliation is complete or nearly complete.

Scab on crabapple fruits was factored into the overall scab ratings.

Table 3. **Apple Scab Ratings for Crabapple Selections at Secrest Arboretum for Crabapples rated on 6-9-98, 7-24-98, and 8-20-98, and the Average Rating for Secrest Arboretum from 1997-1998.**

Crabapple	6-9-98	7-24-98	8-20-98	97–98 Avg.
'Adirondack'	0.0	0.0	0.0	0.0
'Camelot'	0.0	0.0	0.0	0.0
'Canary'	2.3	2.0	2.0	2.2
'Candymint'	0.0	0.0	0.0	0.0
'Glen Mills''	0.6	2.3	3.0	2.2
'Golden Raindrops'	0.0	0.0	0.0	0.0
'Lancelot'	0.0	0.0	0.0	0.1
'Louisa'	0.0	0.0	0.0	0.0
'Naranganset'	1.0	2.0	2.0	1.9
'Pink Satin'	0.6	2.0	2.3	1.7
'Prairie Maid'	0.0	0.0	0.0	0.0
'Purple Prince'	0.0	0.0	0.0	0.0
'Silver Drift'	0.6	1.3	1.3	1.1
'Sinai Fire'	0.0	0.0	0.0	0.0

0 = No scab noted.
1 = Slight scab; less than 5% of leaves affected; no negative effect on aesthetics.
2 = Moderate scab; 50%–20% of leaves affected; some yellowing; little or no defoliation; moderate negative effect on aesthetics.
3 = Extensive scab; 20%–50% of leaves affected; significant defoliation and/or leaf yellowing; significant negative effect on aesthetics.
4 = Heavy scab; 50%–80% of leaves affected; severe defoliation and discoloration of leaves; severe negative effect on aesthetics.
5 = Extreme scab; 80%–100% of foliage is affected and defoliation is complete or nearly complete.

Scab on crabapple fruits was factored into the overall scab ratings.

Comprehensive Aesthetic Evaluations of Crabapples at Secrest Arboretum in Wooster: 1993–1998

James A. Chatfield, Erik A. Draper, Kenneth D. Cochran, Peter W. Bristol, and David E. Allen

Summary

Twenty-eight crabapples (*Malus* spp.) planted in 1984 were rated from 1992–1998 for aesthetic qualities, flower duration, season of fruit effectiveness, tree form, and disease characteristics. Fourteen crabapple selections, which were planted in 1994, were also evaluated for those same parameters for only two years (1997–1998). Overall profiles of these crabapples developed from these ratings are presented in this report. Fifteen crabapples were removed from the evaluation plots due to their consistent lack of pleasing ornamental aesthetics.

Introduction

Crabapples are generally thought of and used mainly as a flowering tree, creating a welcome relief of blossoms in spring landscapes. However, this ornamental tree offers many seasonal impacts beyond the "flowering tree" label. Often ignored are aesthetic qualities like ornamental fruit effect and changing fruit color, leaf shape and fall color, bark exfoliation and tree form. The purpose of this on-going study is to develop an accurate year-round profile of commonly used ornamental crabapples. This profile benefits commercial landscapers, nursery-owners, landscape architects, and home-owners alike in their selection of a particular crabapple for a specific landscape use. Understanding the strengths and the weaknesses of each crabapple increases the likelihood of complementing the landscape, rather than causing a detraction.

Materials and Methods

Twenty-eight crabapples at The Ohio State University/Ohio Agricultural Research and Development Center's Secrest Arboretum were rated monthly for aesthetic characteristics from September 1992 through October 1998. Three ratings were taken each year during bloom and combined for one average value. Ratings were made on a 1–5 basis with 1 = outstanding flower, fruit, foliage, form, and other qualities at time of rating. Results are presented as averages, over the six years, in Table 1.

Similar results for an additional fourteen crabapple selections, which were planted in 1994, and the monthly observations from November 1996 to October 1998 are also presented as averages in Table 1. These selections are noted with an "*" before the crabapple name.

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From 1995 through 1998, crabapples were scrutinized for season of fruit impact every other week starting at petal fall. Effective fruit is defined as the period from when the tree's fruit first contributes to tree aesthetics until fruit is no longer ornamental.

From 1995 through 1997, crabapples were studied to determine days of effective bloom from mid-April through May. Effective bloom was defined as starting with the emergence of the first flowers and ending when overall flower effect was no longer ornamental. The average onset of first bloom is reported as E (Early) = last week of April, M (Mid-Season) = first week of May and L (Late) = second week of May.

Apple scab is reported due to the significance of this disease on aesthetics of crabapples. Incidence of scab is derived from the accumulated disease ratings (three to four per year) on crabapples in the plot from 1993 to 1998, except for those indicated with "*", which only have two years of data (1997–1998). Detailed results of disease findings are presented in another article of this publication (see page 50).

The original crabapple plot was planted in 1984 with an additional 14 selections planted in 1994. The plot is in a completely randomized block design with three replications of each crabapple. The cultural practices used to maintain the crabapple plot are minimal pruning, a six- to eight-foot-diameter mulch ring of a one- to two-inch depth around each tree, and removal of rootstock suckers and dead branches, thereby mimicking those cultural practices of an average landscape.

Results and Discussion

In the authors' opinion, there are some ornamental crabapples that should not be used in the landscape due to an overall lack of aesthetic qualities. This deficiency of aesthetics may be in part due to extensive defoliation or fruit deformation from apple scab, ungainly tree form, retention of mummified fruit, sparse clusters to no fruit, coarse or dull fruit finish, cluttered branching structure, or a general lack of ornamental appeal. Any combination of these aesthetic defects would be extremely difficult to overcome. The trees (listed in Table 3) have been removed from our evaluation plots.

The aesthetic qualities of 42 crabapples (Table 1) were evaluated monthly. Those preceded by a "*" only have two years of observations, from November 1996 to October 1998. All other crabapples have been rated for five years. Monthly ratings are combined and an average derived for each crabapple selection. This mean is useful in determining the true character profile of a crabapple. Although there are both high and low ratings during a single year, averaging the ratings should eliminate uncharacteristic fluctuations. This cumulative mean is therefore the best indicator of how a crabapple will perform aesthetically in the landscape.

When aesthetic quality is combined with disease resistance, then customer satisfaction and success will increase. However, this does not mean that any tree that fails to exhibit complete resistance to scab should be avoided in the landscape. There are trees that have a trace of scab that are absolutely superb and would be great additions to any landscape.

An observation worth noting was the impact that the "El Niño phenomenon" had on crabapple bloom. In 1996 and 1997, 'Dolgo' was the first crabapple to bloom — on the 27th of April. This year 'Dolgo' bloomed a full three weeks ahead of the past two years — on the 6th of April — with all other trees following that general trend.

Also of interest was the conspicuous lack of foliage on some crabapples that bore copious amounts of fruit in 1997 and retained that fruit well into the winter months.

(Text continues on page 102.)

Table 1. Aesthetic Evaluations of Crabapples at Secrest Aboretum: 1993–1998. A "*" preceding the crabapple selection indicates only two years (1997–1998) of observations.

	Fruit		Flower			
Crabapple	Fruit Color	Season of[1] Impact	Bloom[1] Color	Bloom[2] Days	Bloom[2] Time	Tree Form
*'Adirondack'	orange-red	late Aug. to mid-Dec.	white	12.0	L	narrow upright
M. baccata 'Jackii'	maroon red	late July to mid-Dec.	white	10.3	E	rounded upright
'Beverly'	pink-red	late July to late Sept.	white	14.3	E	upright spreading
'Bob White'	yellow	mid-Oct. to late Jan.	white	14.5	M	rounded
*'Camelot'	rose-pink	mid-June to late Oct.	white	14.0	L	low spreader
*'Canary'	yellow	mid-Aug. to early Dec.	white	12.0	M	open spreader
*'Candymint'	red-purple	early July to late Dec.	pink	14.0	M	low spreader
'David'	scarlet	mid-Sept. to mid-Nov.	white	13.7	M	rounded
'Dolgo'	red-purple	early Aug. to mid-Sept.	white	13.7	E	broadly rounded
'Donald Wyman'	bright red	mid-Sept. to late Mar.	white	15.5	L	broadly rounded
M. floribunda	yellow	mid-Oct. to early Nov.	white	12.3	M	broadly spreading
*'Glen Mills/ Winter Gem'	bright red	late Aug. to mid April	white	10.0	M	rounded spreader
*'Golden Raindrops'	yellow	mid-Oct. to early Dec.	white	10.0	L	open spreader
'Harvest Gold'	yellow	late Oct. to mid-Dec.	white	11.0	L	upright

Scab[3]	Aesthetic Rating[3] 93–98 Avg.	Comments ☺: positive aspects ☹: negative aspects
none	2.8	☺: narrow upright form; red-tinged flowers; nice autumn fruit/foliage effect; fruit darkens with time to deep orange-gold; ☹: fruit scattered; leafhoppers like foliage.
none	2.8	☺: glossy green foliage; wonderful fall yellow foliage accents the maroon fruits; bark has orange cast; ☹: sparse fruit clusters; mediocre winter appeal.
none	3.5	☺: abundant fruit; consistent floral display is fabulous; ☹: fruits only half-eaten by birds; large, persistent fruit mummifies into muddied, black blobs until spring.
none	2.9	☺: abundant yellow-gold fruits mature to orange-gold; standout for winter landscape; unbelievable bloom; ☹: alternate bloom; lacking summer appeal.
trace	3.0	☺: low spreading form; fuschia-tinged flower; oblong fruit; foliage dark green with burgundy overtones; ☹: dull leaf appearance; slow growing.
minor	3.1	☺: clusters of tiny fruit; nice autumnal fruit/foliage effect; ☹: some defoliation caused by scab; fruit deteriorates turning cider-brown then falls off.
none	2.2	☺: great overall form; reliable fruit/flower display; purple-tinged leaves; burgundy stems and fruit; new foliage is burgundy red; ☹: slow growing; dull leaf appearance.
trace	3.3	☺: snow-white flower display; impressive cherry-like fruits; ☹: alternate bloom; large mummies hang until mid-winter; mediocre appeal until bloom.
none	3.9	☺: consistent early, large, fragrant blooms; edible, large neon red-purple fruit; ☹: rotten fruit is an intoxicating mess; big, brown mummies are ugly.
minor	2.4	☺: excellent floral display; glossy, exfoliating trunk bark; persistent fruit a mud-red after freeze; ☹: mummies; heavy fruit scab repeatedly threatens overall appeal.
trace	3.0	☺: commingling of yellow and cider brown fruit; wonderful airy floral display; ☹: three-week fruit display; yellow flecking of foliage; mediocre tree most of the year.
major	2.4	☺: petite, profuse fruit is sensational; long-lasting fruit effects; fast growing; ☹: large tree; mediocre summer appeal.
none	2.5	☺: interesting cutleaf foliage; petite abundant fruit; reliable fruit/flower display; great autumnal leaf color; yellow-orange bark; ☹: bland green fruit through summer.
major	3.4	☺: yellow-gold fruit clusters accented by red pedicel; ☹: long period of green fruit; extensive scab yearly; awkward tree form; fireblight is a concern.

Table 1 (continued). Aesthetic Evaluations of Crabapples at Secrest Aboretum: 1993–1998. A "*" preceding the crabapple selection indicates only two years (1997–1998) of observations.

	Fruit		Flower			
Crabapple	Fruit Color	Season of[1] Impact	Bloom[1] Color	Bloom[2] Days	Bloom[2] Time	Tree Form
'Indian Magic'	red-orange	mid-June to early Apr.	pink	13.7	M	rounded
'Indian Summer'	red	early June to mid-Feb.	rose-red	14.0	E	rounded
*'Lancelot'	yellow	early Oct. to early Dec.	white	12.0	L	dense upright
'Liset'	maroon-red	early July to mid Dec.	rose-red	14.5	L	open rounded
*'Louisa'	lemon-gold	late July to mid-Dec.	pink	13.0	E	true weeper
'Mary Potter'	red	mid-Aug. to late Nov.	white	11.5	L	weeper spreader
'Molten Lava'	red	early Aug. to mid-Dec.	white	13.0	M	broad spreader
*'Naragansett'	cherry-red	early Sept. to mid-Dec.	white	15.0	M	broadly rounded
'Ormiston Roy'	orange	late Aug. to late Mar.	white	13.0	M	broadly rounded
*'Pink Satin'	dark red	mid-Aug. to mid-Oct.	pink	10.0	L	upright spreading
*'Prairie Maid'	rosy-red	early June to late Nov.	deep pink	13.0	L	rounded
'Prairifire'	purple-red	late June to early Dec.	coral-red	13.2	L	rounded
'Prof. Sprenger'	orange-red	late Sept to mid-Nov.	white	12.2	M	upright spreader

Scab[3]	Aesthetic Rating[3] 93–98 Avg.	Comments ☺: positive aspects ☹: negative aspects
major	2.6	☺: incredible fruit display; consistent, profuse floral display; persistent fruit; fall foliage color; ☹: yearly leaf scab and defoliation by mid-summer.
major	3.0	☺: prolific fruit display; consistent large blooms; orange fall foliage; flaky bark on trunk; ☹: yearly extensive leaf scab; persistent mummies.
none	2.9	☺: diminutive size; consistent tree form; fruit mix of yellow and cider; ☹: tight dense branching structure; fruit/flower mostly hidden on the interior of the plant.
trace	3.3	☺: attractive fruit display; red-maroon new foliage turning bronze green; ☹: awkward splayed form; mummies; minimal fruit to foliage contrast.
none	1.8	☺: outstanding tree form is its greatest asset; arching, graceful branches upswept at ends; fruit darkens to gold-orange with a rose blush; ☹: scattered, sparse fruit.
trace	2.2	☺: consistent, petite, abundant fruit; fantastic floral display; elegant arching, spreading tree form; salmon-colored underbark; ☹: mummies distract mid-winter.
minor	1.8	☺: outstanding fruit/fall foliage combination; excellent horizontal layered branching; consistent bloom; ☹: somewhat cluttered with maturity; dense; lacks summer appeal.
major	3.1	☺: consistent bloom; abundant firm fruit; ☹: cluttered dense branching structure; severe fruit scab; scabby leaves remain on the tree; tree form awkward.
trace	2.6	☺: wonderful glossy, oval-shaped persistent fruit with rosy blush; orangish bark deeply furrowed; good floral display; ☹: mummies may remain up to a year.
minor	3.5	☺: nice true pink bloom; ☹: abundant persistent blackened mummies are overwhelming; heavy fruit scab; cluttered branch structure.
none	2.6	☺: reliable wonderful bloom; abundant clusters of fruit; new foliage is burgundy red; ☹: lacks winter appeal; waxy coating dulls fruit finish until coating weathers off.
none	2.3	☺: firm fruits slowly age to cherry-red before dropping; yearly spectacular bloom; airy structure; peach-orange fall color; ☹: lacks winter and early summer appeal.
trace	3.6	☺: consistent, large flower display; ☹: dull appearance of large yellow-green fruits during summer; muddied mummies persist until late winter; awkward tree form.

Table 1 (continued). Aesthetic Evaluations of Crabapples at Secrest Aboretum: 1993–1998. A "*" preceding the crabapple selection indicates only two years (1997–1998) of observations.

Crabapple	Fruit: Fruit Color	Fruit: Season of[1] Impact	Flower: Bloom[1] Color	Flower: Bloom[2] Days	Flower: Bloom[2] Time	Tree Form
*'Purple Prince'	blue purple	late June to late-Dec.	rose red	13.0	E	broadly round
Red Jade'	red	late Aug. to mid-Nov.	white	13.0	M	weeper spreader
'Red Jewel'	cherry red	early Sept. to mid-Apr.	white	13.0	L	narrow upright
'Red Splendor'	red	late May to mid-Nov.	rose pink	15.5	E	upright spreading
M. sargentii	red	mid-Aug. to early Nov.	white	11.2	L	wide spreader
'Sentinel'	red	late Sept. to early Mar.	white	13	M	narrow upright
*'Silver Drift'	cherry red	mid-Sept. to mid-Apr.	white	13	E	broadly round
'Silver Moon'	burgundy	early Sept. to mid-Dec.	white	9.2	L	oval upright
*'Sinai Fire'	red-orange	mid-Aug. to late Oct.	white	14	M	unique spreader
'Snowdrift'	salmon-red	mid-Aug. to mid-Nov.	white	10.2	M	broadly rounded
'Strawberry Parfait'	red-cream	mid-Aug. to mid-Apr.	pink	14.7	E	open spreading
'Sugar Tyme'	bright red	early Sept. to mid-Apr.	white	13	M	rounded
'White Angel'	red	mid-Oct. to early Feb.	white	9.7	M	broadly rounded

Scab[3]	Aesthetic Rating[3] 93–98 Avg.	Comments ☺: positive aspects ☹: negative aspects
none	2.6	☺: dark large unusual colored fruit; consistent flower/fruit display; fast growing; leaves deep purple green; ☹: lacks fruit/foliage contrast; lacking winter appeal.
minor	2.2	☺: large, prolific bloom; reliable fruit and flower display; graceful arching, spreading growth habit; ☹: unsightly fruit rot in Jan.; scab on fruit can dull appearance.
none	2.5	☺: phenomenal persistent firm fruit; great flower display; can become alternate bloomer; ☹: tree form is somewhat upright and ungainly.
major	3.3	☺: exceptional profuse red fruits; fruit matures to orange-salmon color; reliable fruit/flower display; ☹: heavy scab may defoliate tree; severe Japanese beetle feeding.
none	2.8	☺: petite firm fruits; attractive low-spreading form; reliable fruit/flower display; ☹: fruits rapidly deteriorate and shrivel like raisins.
minor	2.9	☺: persistent firm small fruits; spectacular pink-tinged bloom; reliable fruit/flower display; ☹: persistent mummies are detracting; fruit scab dulls appearance.
trace	2.7	☺: nice persistent showy fruit, nice fruit/new leaves contrast; fast-growing tree; ☹: some fruit mummies; fruit obscured by foliage.
none	3.0	☺: glossy unique colored fruits; good late floral display; peculiar tree form; ☹: erratic alternating bloomer; densely cluttered growth; fireblight can be a problem.
none	2.5	☺: uncommon growth habit; good specimen plant; large flowers; consistent bloom; ☹: scattered sparse fruit; unique form can limit usage; slow growing.
major	2.9	☺: reliable excellent flower display; distinctly colored, small round fruits and pedicels; ☹: fruits shrivel by late fall; chlorotic summer foliage; extensive leaf scab.
trace	2.3	☺: unbelievable floral display; red-tinged newly emerged foliage; unusual growth form; firm persistent fruits; ☹: persistent fruit mummies.
trace	2.4	☺: reliable fruit/flower displays; abundant persistent fruits; stunning sugar white flowers; good tree form; ☹: fruit drops all at once before bloom.
none	3.2	☺: abundant fruits; reliable fruit/flower display; attractive bloom; ☹: awkward growth form until tree matures; mummified fruit hangs until spring.

Table 1 (continued). **Aesthetic Evaluations of Crabapples at Secrest Aboretum: 1993–1998. A "*" preceding the crabapple selection indicates only two years (1997–1998) of observations.**

	Fruit		Flower			
Crabapple	Fruit Color	Season of[1] Impact	Bloom[1] Color	Bloom[2] Days	Bloom[2] Time	Tree Form
'White Cascade'	yellow	None - scab ravaged	white	14.2	M	true weeper
M. zumi 'Calocarpa'	bright red	late Aug. to mid-Dec.	white	12.2	L	rounded spreader

* Denotes crabapple selections for which there are only two years (1996-1998) of observations.

1 Season of fruit impact derived from biweekly observations from 1995-1998 only. Effective fruit impact is defined as the period from when the tree's fruit first contributes to tree aesthetics until the fruit is no longer ornamental.

2 Bloom days and bloom time are derived from daily observations from April-May in 1995-1997 only. For bloom time, E (Early) = onset of first bloom in April; M (Mid-season) = onset of first bloom in first week of May; and L (Late) = onset of first bloom in second week of May. Bloom days are defined as starting with the emergence of the first flower and ending when overall flower effect was no longer ornamental.

3 Scab and aesthetic ratings are from 1993-1998 unless a "*" is present by the crabapple name which denotes there is only data from two years (1996-1998) of observations.

Scab Rating Scale

None = No scab noted.
Trace = A few leaves affected; no negative effect on aesthetics.
Minor = 20%–50% of leaves affected; significant defoliation and/or leaf yellowing; negative effect on aesthetics.
Major = 50%–90% of leaves affected; severe defoliation and discoloration of leaves; almost complete negation of any aesthetic effect.

During the growing season, it was observed that some branches, with last year's fruit mummies still present, had died. Some of these branches did begin to leaf out, but the foliage was small, stunted, and never expanded to a normal size. With the mild winter experienced in the area, this condition was definitely not due to freeze damage. One possible explanation is that the large fruit load exhausted the carbohydrate supply, creating additional stresses on trees, resulting in branch dieback.

The authors believe enough observations have been conducted on the original 28 trees to confidently state that the crabapple profiles created are reasonably accurate representations of how that crabapple will perform. The other 14 crabapples, designated by a "*", were evaluated for just two years, so the aesthetic mean and bloom length for these trees should be considered approximations. Therefore, the profiles of these "newer" crabapples may not be an accurate or complete representation of their aesthetic qualities. More research is needed to confirm these findings and/or correct the inaccuracies.

Scab[3]	Aesthetic Rating[3] 93–98 Avg.	Comments ☺: positive aspects ☹: negative aspects
major	3.0	☺: exquisite flower display on cascading branches; appealing weeping form; ☹: dingy summer appearance due to extensive fruit and foliage scab.
trace	3.0	☺: reliable fruit/flower display; abundant tiny red fruits; excellent floral show; nice tree form; ☹: shriveled fruits; lacks winter appeal.

Aesthetic Rating Scale

Ratings include flower, foliage, form, and fruit characteristics, and effects of disease and pest problems. The rating system is as follows:

1 = Exceptionally ornamental crabapple. Based on outstanding flower, foliage, fruit, or form at time of rating.
2 = Highly ornamental crabapple. Good flower, foliage, fruit, or form at time of rating.
3 = Adequate as a landscape crabapple. Not highly ornamental at time of rating.
4 = Substandard as an ornamental crabapple at time of rating.
5 = Ornamentally unacceptable as a landscape crabapple at time of rating. Not recommended for use in the landscape.

It must be noted that these crabapple profiles of fruit, flower, form, and disease observations are limited to one site, Secrest Arboretum in Wooster, Ohio. Other limitations of this study that can affect ratings are the preferential biases of the evaluators as well as the inability to keep environmental conditions uniform. The lack of control over environmental conditions can directly impact aesthetic aspects like return bloom, bloom duration, fruit development, and, ultimately, tree size and form, if conditions become severe.

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Table 2. Ornamental Crabapples Removed From the Evaluation Plot Due to Severe Scab Problems and/or Lack of Other Pleasing, Consistent Aesthetic Qualities.

'Adams'	'Red Barron'
'Centurion'	'Robinson'
M. halliana 'Parkmanii'	'Royalty'
'Henningii'	'Ruby Luster'
M. adstringens 'Hopa'	'Selkirk'
'Profusion'	'Velvet Pillar'
'Radiant'	'Weeping Candied Apple'
'Ralph Shay'	

Comprehensive Aesthetic Evaluations of Crabapples at Secrest Arboretum in Wooster, Ohio: 1993–1997. *Ornamental Plants: Annual Reports and Research Summaries.* Special Circular 157. Ohio Agricultural Research and Development Center. The Ohio State University. pp. 83–94.

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Inkberry Leaf Miner, *Phytomyza glabricola* Kulp (*Diptera: Agromyzidae*): Life Cycle in Ohio

Abdulrahman A. K. Al-Siyabi and David J. Shetlar

Summary

Inkberry leaf miner populations were monitored in 1997 and 1998 in Columbus and Wooster, Ohio. It appears that this insect has three and possibly four generations per year in Ohio. The overwintering stage is the pupa, and the adults do not produce pinholes in the leaves.

Introduction

In Ohio nursery production of inkberry (*Ilex glabra*), the plants are usually protected from winter damage by keeping them in plastic-covered temporary houses. This is done so that the plants can be sold early in the season and so that winter scalding can be avoided. Discussions with Randy Zondag (Ohio State University Extension, Lake County, Horticulture Agent) regarding this pest suggested that the plants were being attacked while in winter storage (personal communication). Therefore, from these discussions, the decision was made to study this insect because of its impact on Ohio's production of inkberry.

The native habitat of inkberry plants is Nova Scotia to Florida and west to Mississippi (Dirr, 1983). Dirr also indicated that the native habitat for inkberry is wetland sites. The plant prefers moist, acidic soils.

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Inkberry leaf miner has only been recorded in the northern states (i.e., Washington, D.C.; Maryland; New Jersey; Ohio; and Pennsylvania) (Kulp, 1968). No references could be found recording the presence of *P. glabricola* in southern states.

Of the seven species of leaf miners known to attack holly (Kulp, 1968), only the holly leaf miner, *P. ilicis* Curtis, and the native holly leaf miner, *P. ilicicola* Loew, have had their life histories extensively studied. *P. ilicis* is apparently a native of Europe, and it only attacks European holly, *Ilex aquifolium* L. *P. ilicicola* mainly attacks American holly, *I. opaca*, but the adults may make pinholes on *I. crenata* and *I. aquifolium*. Kulp (1968) believes that *P. ilicicola* may even lay eggs in *I. aquifolium*, but the larvae are unable to complete their development. Almost nothing has been published about *P. glabricola* biology except a speculation by Mathysse (1954). He indicated that inkberry leaf miners have two generations a year, with adults emerging very early in the spring and again in midsummer.

Holly leaf miner eggs are laid in June, usually one per holly leaf, at the base of the underside of the midrib. The young larvae mine the vein until late fall then move to the outer parenchyma during the autumn, where they form clearly visible, large, irregular blotch mines. Larvae pupate in the mines in the following March, emerging from the leaf as adults in late May or June (Head and Lawton, 1983).

The native holly leaf miner also has one generation per year (Hartzell, 1943). The adults emerge in late April into May when the new holly leaves have half expanded. The females feed extensively for about 10 days. Their pinholes can cause severe distortion of the young leaves. The females insert their eggs from the leaf undersurface. This produces a tiny green blister on the leaf surface. The first instar larvae make a narrow mine that appears as a dark brown streak ending in a light green area. Apparently, the larvae feed very slowly during the summer or they remain dormant. In late fall, the larvae produce an elongate blotch, and the larvae pupate in March to April.

Materials and Methods

In Columbus, Ohio, eight inkberry plants were selected for both shaded and sunny sites. Shaded plants were located along the north side of a commercial building, which kept them shaded all the time. Sunny-aspect plants were located in an open area beside a parking lot and road. They were exposed to the direct sun for about 10 hours each day during the summer months. Plants at both locations were about 0.6 m tall and 0.4 m wide and apparently had been established for a minimum of two to three years prior to the study.

In Wooster, Ohio, a second set of plants was located within The Ohio State University/ Ohio Agricultural Research and Development Center's (OARDC) Secrest Arboretum on the Wooster Campus. Because of the landscape style of planting within the Secrest Arboretum, three inkberry plants were identified as being located under or near larger deciduous trees. These were considered to be shaded plants, though the density of the shade was not as complete as was that for the Columbus plants. The sun-aspect plants at Wooster were generally in the sun for at least two-thirds of a day. In other words, they were often in the shade longer in the morning or afternoon than the Columbus sun-aspect plants. These plants were also approximately 0.6 m tall and 0.4 m wide and had been established for several years.

A biased sample of 20 mined leaves/plants was taken on a weekly basis from all sites. If no mined leaves could be found, unmined leaves were taken. The leaves were taped by their petiole to white paper and their upper surface image was recorded by scanning them, using a computer color scanner, Microtek ScanMaker E6™, at 300 dpi. The aim of scanning was to preserve information, such as the size, shape, and color of the mines. Each mine was then opened and inspected under a 10-to-30 dissecting microscope, Olympus SZH™, and data about the stage (1st, 2nd, 3rd instar larva, pupa, or adult, as indicated by a recently vacated pupal case) of the leaf miner were recorded. Data for each stage, collection date, and plant location were entered into a Microsoft Excel™ spread sheet. In order to reduce the magnitude of sampling extremes, a smoothing technique was used, whereby:

smoothed number =

[previous date's number + 2 * current date's number + next date's number] ÷ 4

The resulting "smoothed" data were graphed and life cycles of *P. glabricola* were determined for both locations and sites.

Results and Discussion

Figures 1 and 3 contain charts of the *P. glabricola* first, second, and third instar larval numbers for the sunny and shaded Columbus sites, respectively. In 1997, there appeared to be two first instar larval peaks (≈ Sept. 7 and Dec. 6). However, in 1998, one major peak occurred June 14, but subsequent peaks are difficult to determine. Data for the second and third instars were even less evident.

Figures 2 and 4 contain charts for the inkberry leaf miner pupae and adults from the Columbus sunny and shady sites, respectively. In 1997, there are two pupal population peaks (≈ July 29 and Sept. 17) with a third peak of overwintering pupae. The adult emergence peaks occurred around Aug. 8 and Oct. 7 for the sun-aspect plants and around Aug. 18 and Oct. 17 for the shady site. The population peaks were much more evident from the shady site data.

In 1998, the first adult peak emergence occurred ≈ April 25 for the sun-aspect plants and ≈ May 5 for the shady site. In the sun-aspect site, there appeared to be three more adult flights (emergences) at ≈ June 4, July 24, and Sept. 2, before the sampling was discontinued on Sept. 20. However, in the shade, only two additional adult peaks were noted (≈ July 14 and Sept. 12). Because the pupal and adult numbers are very low in the sun-aspect data, the authors believe that the shade-aspect data are more indicative of the actual adult emergence patterns and represent three generations. The fourth generation, if it exists, can only be speculated about from the 1997 data because the study was stopped on Sept. 20, 1998. In 1997, this generation of adults peaked in the third week of October, and adults continued to be active until early December. The larvae present in October, November, and December of 1997 generally pupated by early December and remained in this state until the following April.

The first, second, and third instar larval numbers are presented for the Wooster sun- and shade-aspect inkberry samples in Figures 5 and 7, respectively. The first instar larval data had one major peak in 1997 (≈ Aug. 28) and two peaks were found in 1998 (≈ May 10 and ≈ Aug. 3). Similar, but much lower in magnitude, peaks were noticed for the second and third instar larvae.

The pupal and adult numbers for the Wooster sun- and shade-aspect inkberries are presented in Figures 6 and 8, respectively. Very low numbers of both stages were seen in the 1997 samples, especially in sun-aspect samples. From the pupal numbers, there appeared to be three minor peaks in 1997 (≈ July 19, ≈ Sept. 17, and ≈ Dec. 6). In 1998, three adult emergence peaks were detected in the sun-aspect samples (≈ May 5, ≈ July 10, and ≈ Sept. 7). However, the shade-aspect data indicated only two pupal and adult peaks (late April to early May, mid-July to mid-August).

Generally, inkberry leaf miner pupae were in the overwintering stage in both Columbus and Wooster. The authors estimated that there were at least three generations of *P. glabricola* in both locations and sites, and a possible fourth. The first generation has adults emerging from overwintered pupae in early April and continuing emergence to the first week of June. The second generation of adults emerged in late June and continued to mid-August. Adult emergence for the third generation appeared in late August, peaked in September, and decreased in early October. The possible fourth generation may have been detected in October–November of 1997, especially in the Columbus site. Further studies will be needed to determine if *P. glabricola* normally has three generations but has the ability to undergo four generations during seasons of prolonged growing conditions.

The adult females did not produce pinholes in the leaves, and in feeding studies showed no interest in inkberry sap. This is very different from the holly and native holly leaf miners.

Significance

Since the inkberry leaf miner appears to have three to four generations per year in Ohio, this pest could cause considerable damage, especially in nursery production.

(Text continues on page 112.)

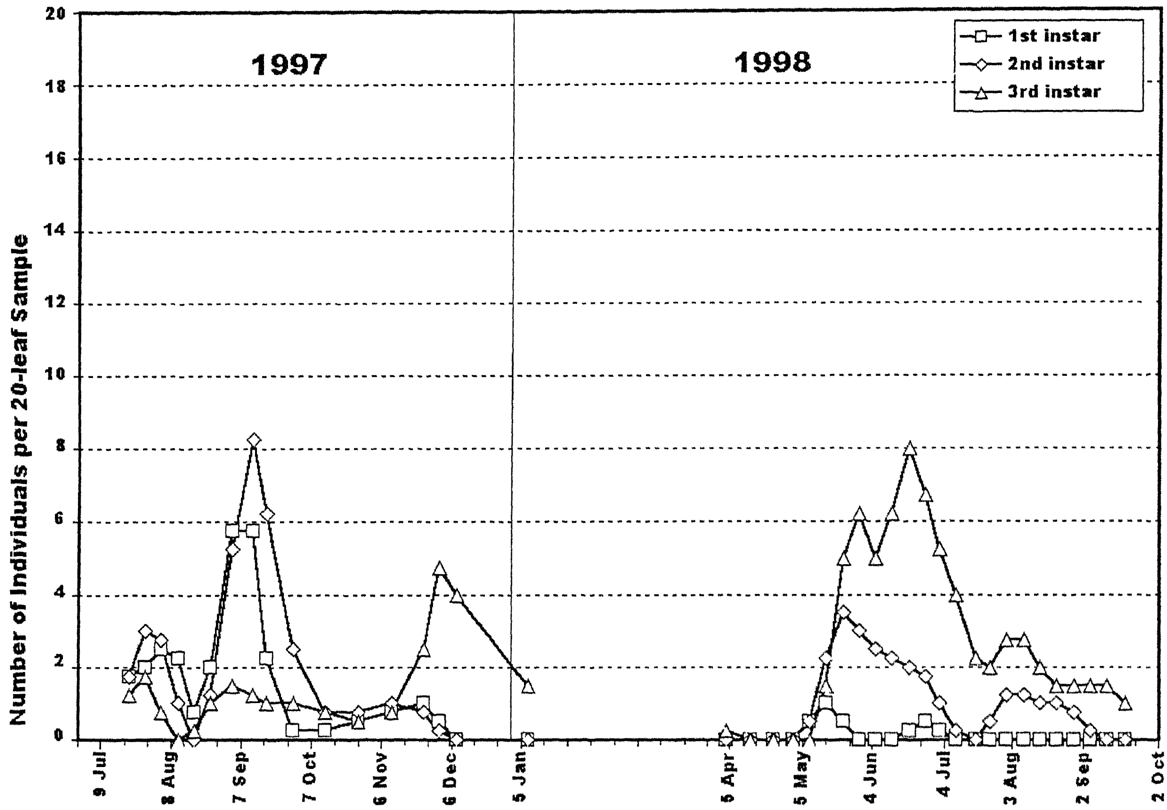

Figure 1. Inkberry leaf miner larval populations from the Columbus shady site.

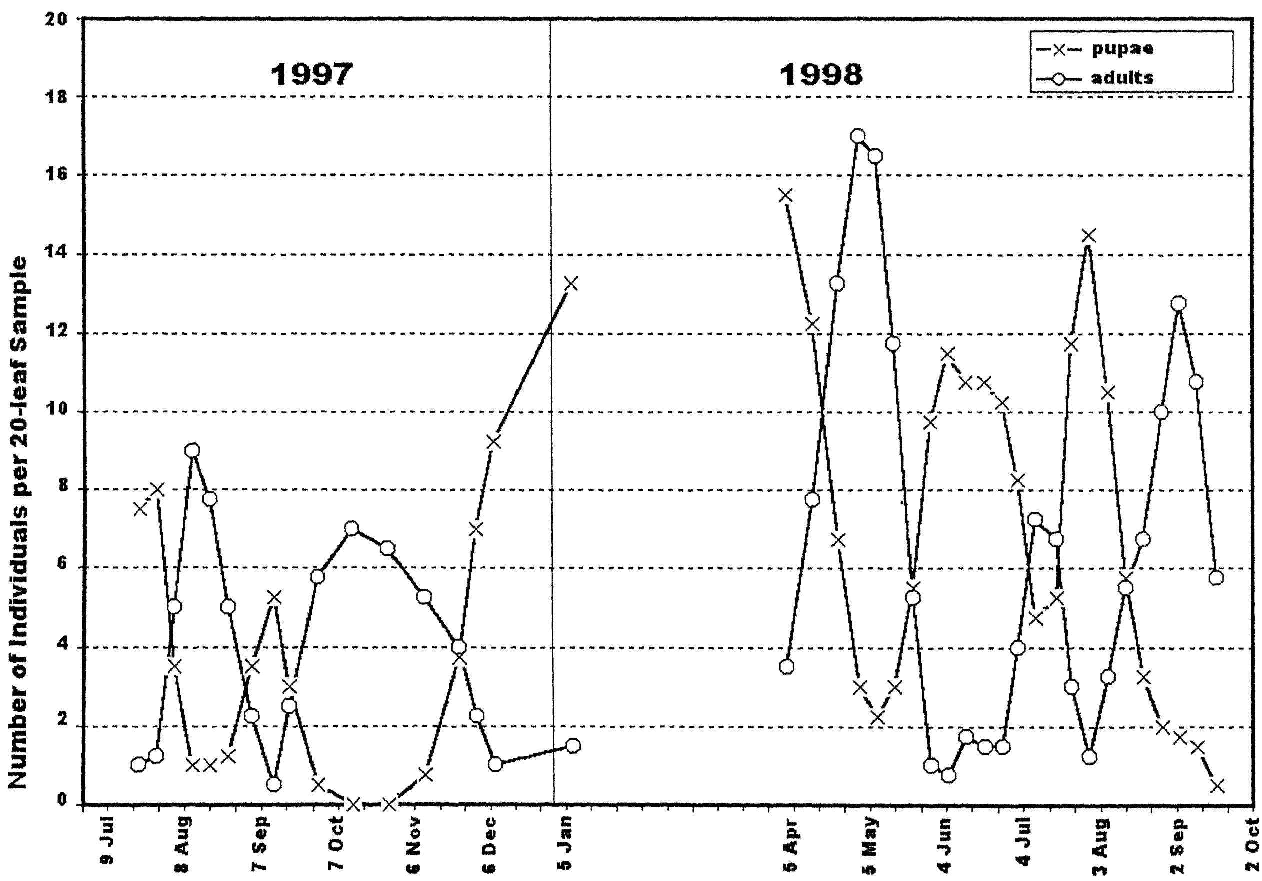

Figure 2. Inkberry leaf miner pupal and adult populations from the Columbus shady site.

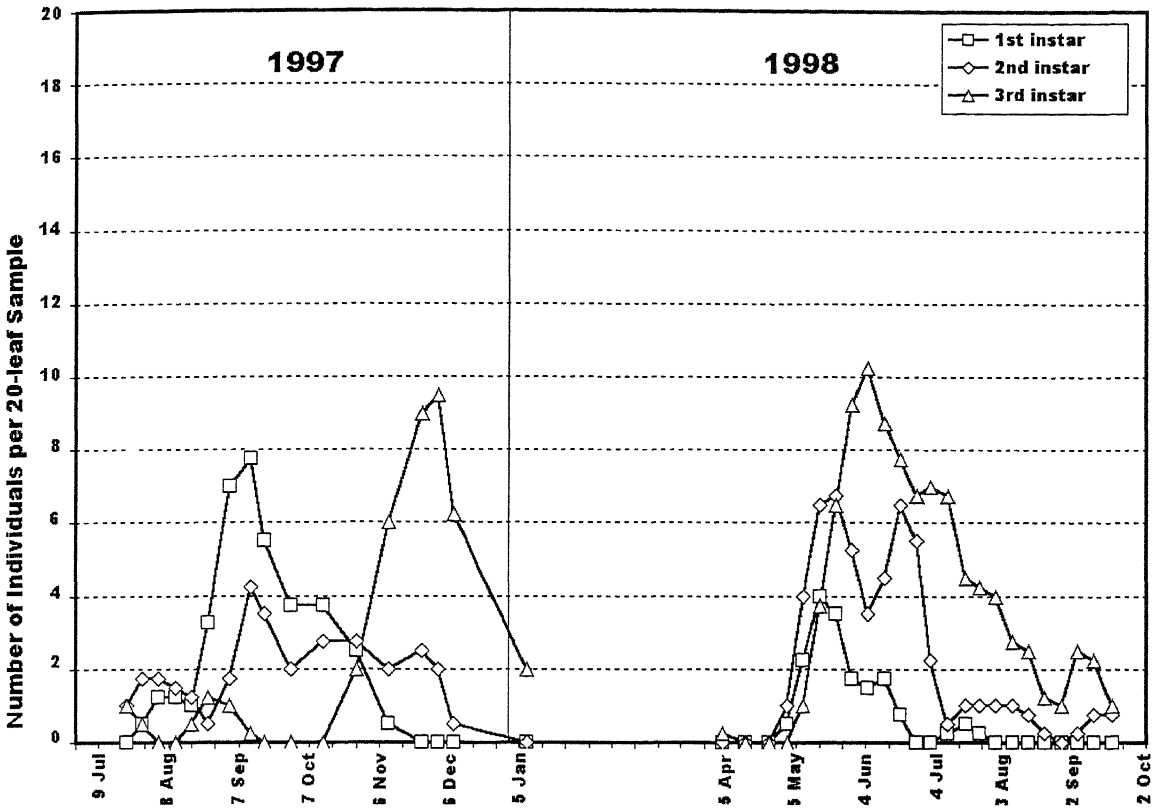

Figure 3. Inkberry leaf miner larval populations from the Columbus sunny site.

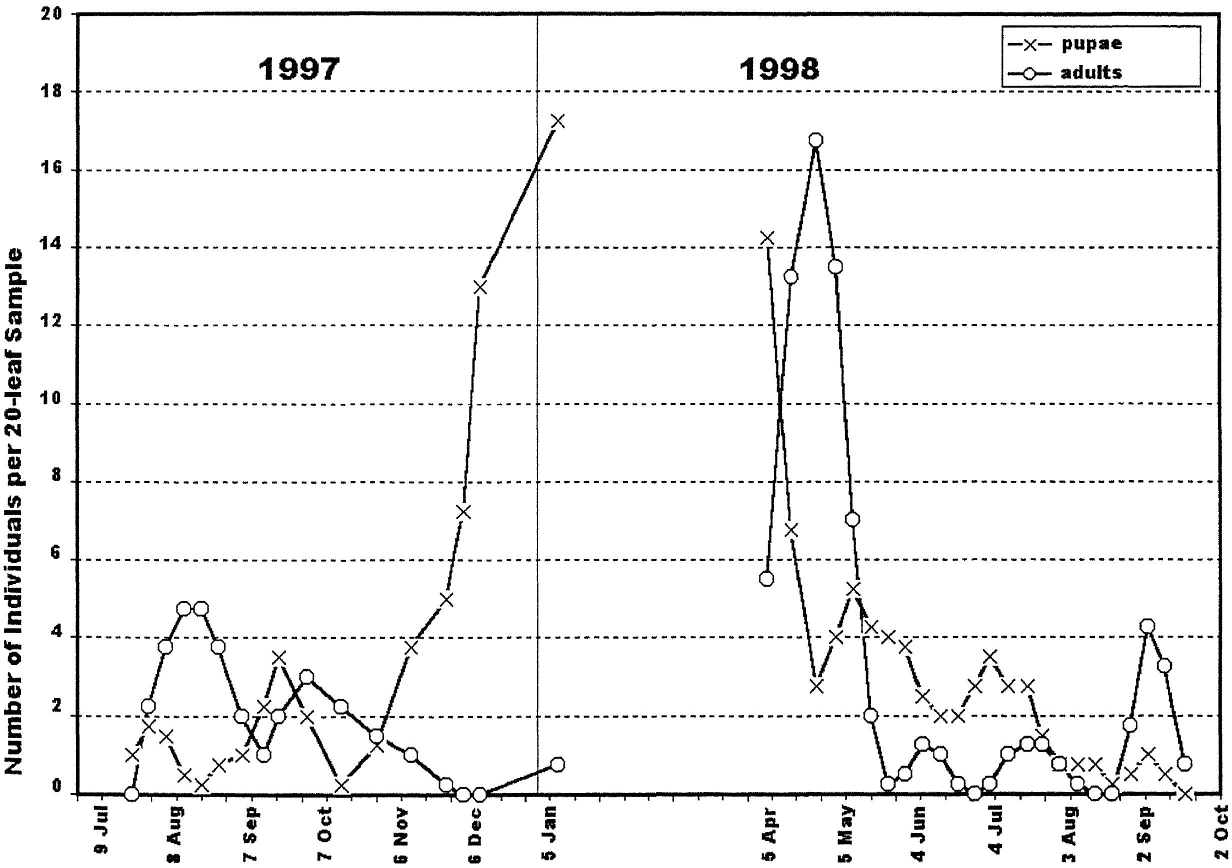

Figure 4. Inkberry leaf miner pupal and adult populations from the Columbus sunny site.

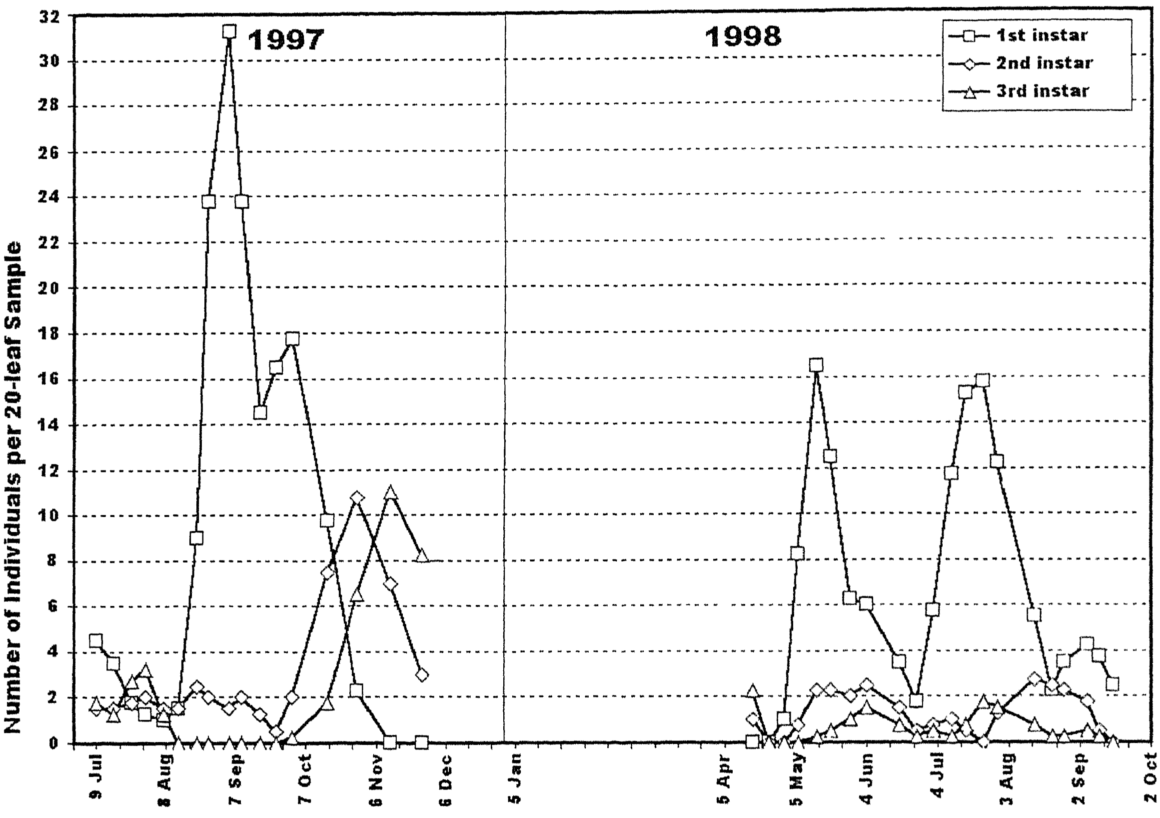

Figure 5. Inkberry leaf miner larval populations from the Wooster shady site.

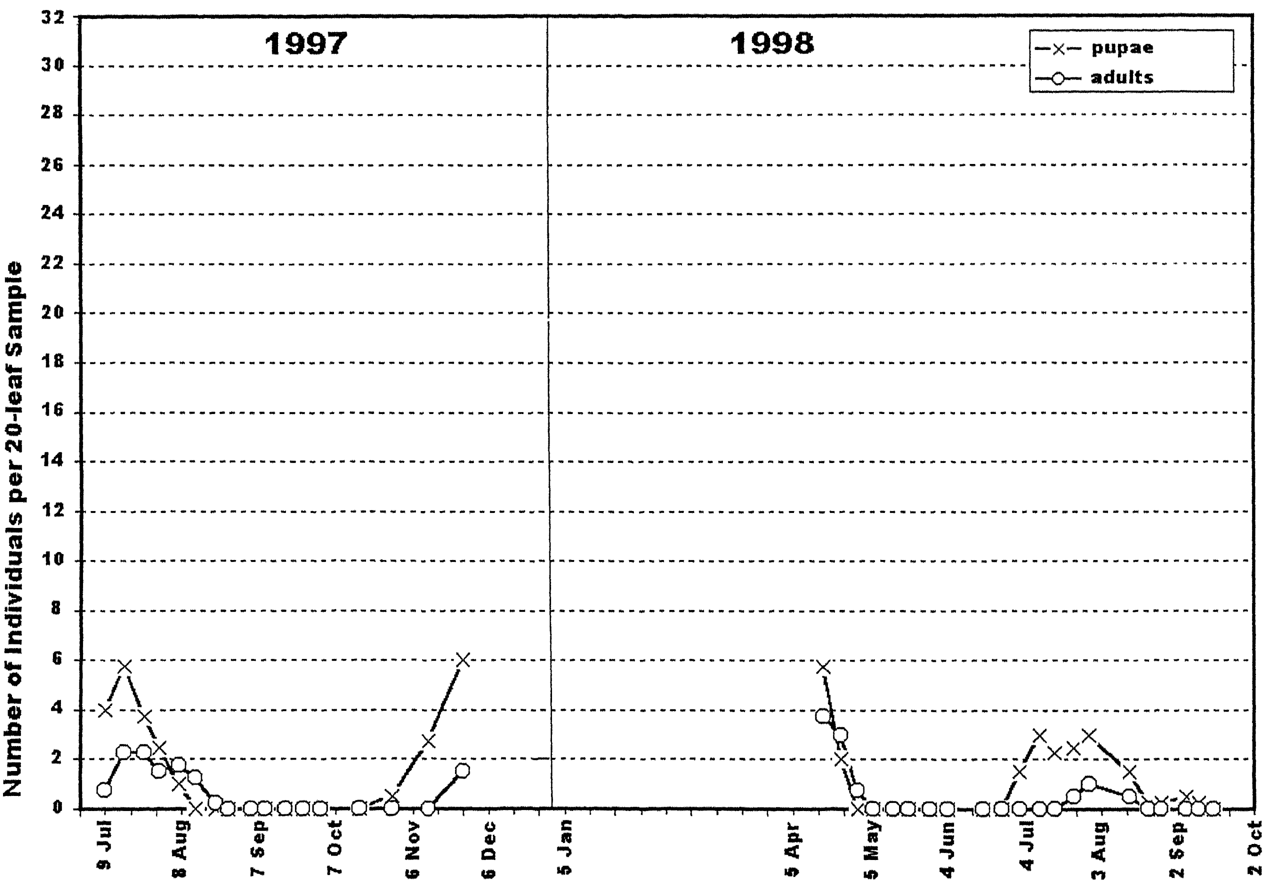

Figure 6. Inkberry leaf miner pupal and adult populations from the Wooster shady site.

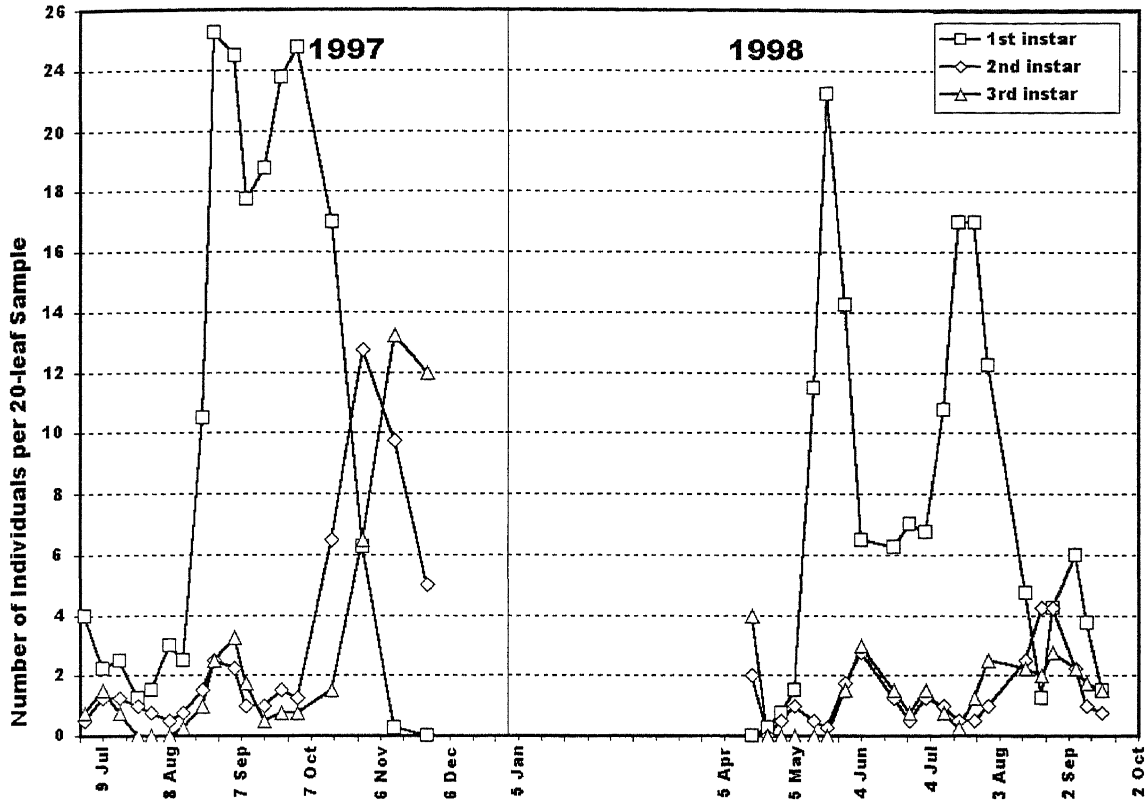

Figure 7. Inkberry leaf miner larval populations from the Wooster sunny site.

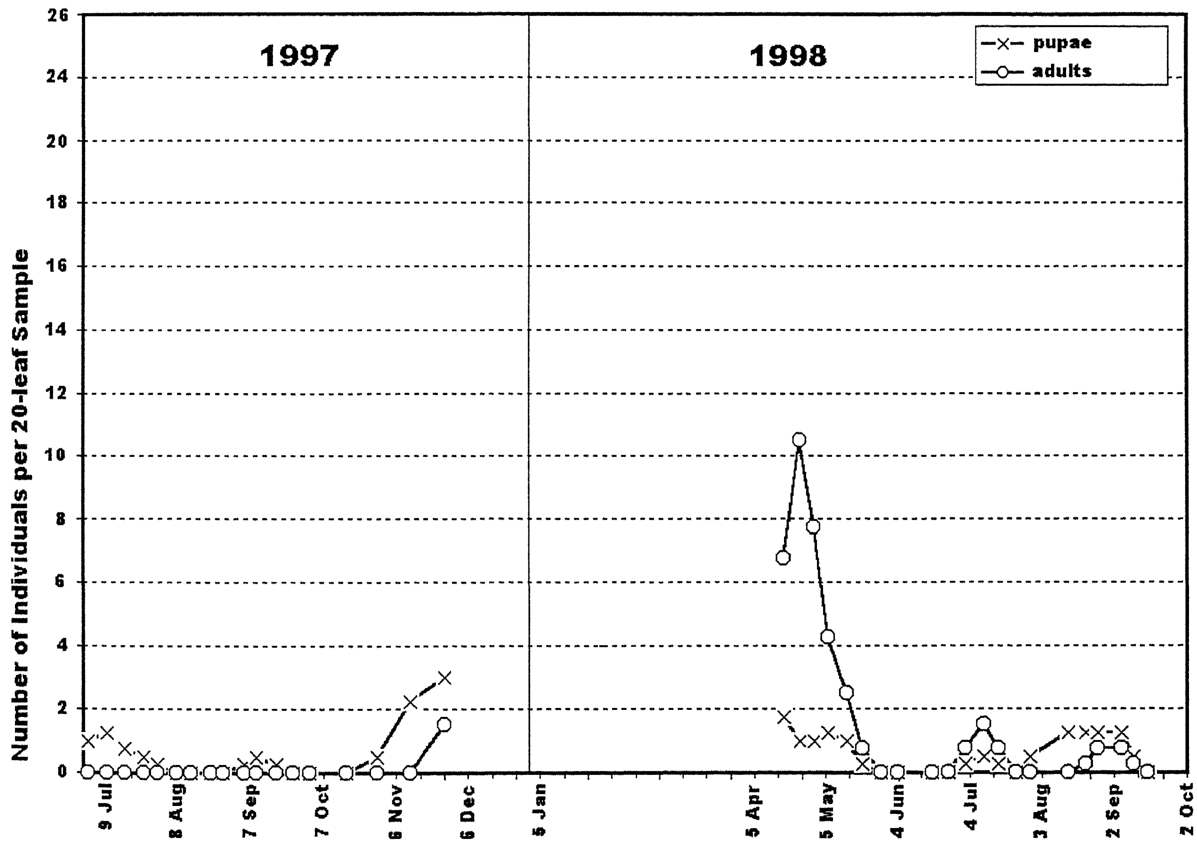

Figure 8. Inkberry leaf miner pupal and adult populations from the Wooster sunny site.

(*Text continues from page 107.*)

Adults from overwintering pupae could, conceivably, emerge in plastic houses during the winter months and lay eggs for another generation. This means that nursery producers may have to treat their plants in September or October to eliminate the larvae before they pupate for the winter.

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Growth of Ornamental Plants in Compacted Soils and Media

Michael Knee, Ruth A. Brake, Nicole D. Cavender, and Laura C. Thomas

Summary

This study investigated the ability of a number of Ohio native grasses and flowering plants to grow in compacted media. In one experiment, three native species grew better in moderately compacted media than five species of traditional bedding plants. Ability to grow in compacted media seemed to be related to the ability of roots to expand under pressure and not to growth at low-oxygen levels. Digital photography and image analysis showed that 11 of 13 species of prairie grasses and forbs (herbaceous flowering perennials) grew larger in compacted topsoil or greenhouse medium than in uncompacted media. Size differences persisted in the field for the first growing season. Type of medium did not influence size at transplanting, but in the field, seedlings from greenhouse medium grew larger than those from topsoil. Seedlings of these species were larger after growth in untilled plots than in tilled areas.

Introduction

In urban situations ornamental plants are often planted in soils that are compacted or have poor structure (1). The silt-loam soils characteristic of much of Ohio are particularly subject to compaction and loss of structure after stripping of native vegetation, construction activity, and everyday human traffic. Plant roots growing in compacted soils experience restricted aeration and physical resistance; these conditions are generally expected to reduce plant growth (2). Native, unselected plant species are sometimes promoted for their ability to tolerate stresses better than exotic species or horticultural varieties. Indeed, one catalog lists a number of prairie grasses and forbs as "clay-busters," raising the expectation that they can tolerate soil compaction (8).

Adaptations to growth in compacted soils could include the ability for roots to grow at low oxygen concentrations or to force apart soil particles (6). This study tested for the ability of the radicle of germinating seeds to elongate at low oxygen concentration or in the presence of high atmospheric pressure. High pressure simulates the resistance of the surrounding media to root cell expansion. Roots could adapt to low oxygen or physical restriction in other ways. For example, roots can develop aerenchyma, open channels through the tissue that allow oxygen to diffuse from the above-ground parts of the plant (5). Adaptations to physical resistance include the secretion of polysaccharides by the root tip that lubricate passage through the soil, or the ability to follow tortuous paths between soil particles (1, 4).

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This study originally set out to test the hypothesis that native plants could tolerate soil compaction better than horticultural bedding plants and to determine whether low oxygen or physical resistance was the important factor. Observing that some prairie species actually seemed to benefit from mild compaction in greenhouse conditions, the study went on to determine whether this was a general response for other species. This study was also interested in determining whether field performance of plants was influenced by production of seedlings in compacted media or by production in soil as opposed to artificial medium. An additional aspect of this research has been to determine whether digital photography can be used for reliable, nondestructive measurement of plant growth.

Materials and Methods

For the first experiment comparing prairie and bedding plants, seedlings were grown in 24-cell flats under a range of soil-compaction levels in field soil (Crosby Silt Loam) or greenhouse medium (Metro Mix 360, W. R. Grace, Cambridge, Mass.). Cells were loosely filled (uncompacted) or packed with a pestle to three compaction levels, the highest being the maximum that could be pressed into the cell with hand pressure.

Macropore space was estimated from the change in weight of water-saturated media that were allowed to drain to field capacity. Plastic tubes were embedded in selected cells for analysis of the soil atmosphere; the lower end of the tube was open and the upper was sealed with a rubber septum at the soil surface. A hypodermic syringe was used to take gas samples through the rubber seal; these were injected into a gas chromatograph set up to analyze carbon dioxide, oxygen, and ethylene.

The bedding plants were grown in the greenhouse for six weeks and the prairie plants for 12 weeks. At the end of this time, shoots were harvested and dry weights were measured.

For the second experiment, 13 species of prairie plants were grown in 48-cell flats in greenhouse medium (Metro Mix 360) or a commercial topsoil (Saginaw Series from Michigan marketed by Southland Soil Products, Greensboro, N.C.). Cells were loosely filled or compacted with an extra 20% of greenhouse medium or 40% of topsoil.

After 12 weeks growth in the greenhouse, seedlings were transplanted to a site in The Ohio State University's Chadwick Arboretum (Columbus) where subsoil from the excavation of a lake had been used to create a mound. A square area on the mound was divided into four plots each 2.25 m^2. Two of the plots were cultivated by turning with a fork to a depth of 25 cm, and two were left uncultivated. Each plot was further subdivided into four areas, each assigned to one of the production treatments (two media and two compaction levels in factorial combination).

Seedlings from appropriate production treatments were set out in each area according to a planting design that was intended to be visually attractive as well as statistically valid. Seedlings were planted with a minimum of soil disturbance, so that in the untilled plot, the roots were in immediate contact with compacted soil.

Plants were photographed with a Kodak DC40 digital camera at the time of transplanting and twice during the first growing season. To provide scale a 30-cm rule was included in the seedling photographs, and a meter rule was included in the plot photographs. Photographs were edited in Adobe Photoshop 3.0 to remove nonplant image, and areas of individual plants were estimated using Sigmascan 1.2. In order to normalize the distribution of error in statistical analysis, plant area data was log-transformed. Back-transformed means are shown in Tables 4 and 5.

Results and Discussion

The greenhouse medium had a much lower bulk density at all compaction levels than the field soil used in the first experiment (Table 1). However, macropore space was similar in the two media at corresponding compaction levels. The oxygen concentration detected in media decreased to a minimum of approximately 12% (Table 2) as compaction increased. This seems to have been a function of soil respiration since oxygen concentration was not affected by plant species or even the absence of a plant from a cell. Carbon dioxide concentration increased with compaction, but to a lesser extent than the oxygen decreased. Ethylene concentration tended to decrease with compaction but concentrations were usually less than 0.1 $\mu l\ L^{-1}$ (Table 2).

Table 1. Physical Properties of Media in Cells (Volume 170 ml) of Flats Used in Experiment 1.

Medium	Compaction Level	Mass (g)	Bulk Density (g ml-1)	Macropore Space (ml g-1)
Greenhouse mix	0	23	0.137	0.348
	1	28	0.164	0.285
	2	33	0.203	0.180
	3	38	0.231	0.143
Field soil	0	150	0.882	0.294
	1	165	0.976	0.223
	2	180	1.077	0.170
	3	195	1.155	0.058

Table 2. Average Gas Concentrations Detected During Three Months in Media of Cells Containing *Asclepias Tuberosa* in Experiment 1.

Medium	Compaction Level	Oxygen (%)	Carbon Dioxide (%)	Ethylene ($\mu l\ L^{-1}$)
Greenhouse mix	0	20.2	0.47	0.103
	1	16.9	0.49	0.098
	2	16.2	1.24	0.096
	3	12.4	1.55	0.081
Field soil	0	16.5	0.62	0.108
	1	17.1	0.86	0.099
	2	16.1	0.86	0.085
	3	12.8	1.27	0.085

Because there were large differences in the growth of plant species, dry weights were normalized relative to the average for a species:

normalized weight =

actual dry weight ÷ average dry weight

After this manipulation, it is possible to compare effects of medium and compaction level without being distracted by species effects (Figure 1). Higher levels of compaction tended to reduce the dry weight of all species in both media; the first compaction level tended to decrease the dry weight of bedding plants and to increase the dry weight of the prairie species, *Asclepias, Echinacea,* and *Schizachyrium* (Figure 1). Some species (*Tagetes, Zinnia,* and *Echinacea)* had higher dry weight in the greenhouse medium than in field soil, whereas *Impatiens* was higher in field soil than in greenhouse medium. Other plants showed similar growth in both media.

Germinating seeds of the same species were grown for three days in different oxygen concentrations. The relationship between radicle growth and oxygen concentration was examined to determine the concentration at which elongation occurred at half of the maximum rate ($C_{0\,5}$). This concentration varied according to species from 0.74% for *Schizachyrium scoparium* to 4.98% for *Zinnia elegans* (Table 3). There was no obvious relationship between growth in compacted soil and $C_{0\,5}$. Germinating seeds were also exposed to high atmospheric pressure. Radicle elongation was more sharply reduced by pressure for the bedding plants than for the prairie species. The contrast was particularly clear at 1.14 MPa (11.4 bar) where radicle length of the bedding plants was reduced by 55% or more, but growth of the prairie species was reduced by 20% or less (Table 3). Root response to pressure did not account for all of the responses to soil compaction in the greenhouse experiment. However, there was a correlation between response of whole plants to the first compaction level and the response of radicle elongation to 1.14 MPa (Figure 2).

In the second experiment, a wider range of prairie species was grown in two kinds of media and at two compaction levels. At the time of transplanting, the size of seedlings in topsoil and greenhouse medium was similar, but seedlings in compacted media were larger than those in uncompacted media (Table 4). The larger size of plants from compacted than from uncompacted media was maintained in the field, but the proportional difference tended to decrease (Tables 4 and 5). The size of plants from seedlings raised in greenhouse mixture increased faster than those from topsoil, and plants in untilled soil grew larger than those in tilled soil (Table 5).

Although severe compaction adversely affects plant growth, soil can also be too loose. There appears to be an optimum level of compaction at which root-soil contact is maximized, but root growth is not restricted (6). The rate of plant growth at any time tends to be proportional to plant size, so relative differences in size are expected to persist, as they did in the second experiment. In research with lettuce transplants, seedlings grew larger in compacted media than in uncompacted, but the difference did not persist in the field (7). It is sometimes argued that artificial media may be ideal for plant growth in the greenhouse, but that plant roots may have difficulty growing into mineral soil when planted out in the field. From this research it appears that there is no advantage over greenhouse medium in the use of topsoil to produce seedlings of the plant species tested. From the comparison with bedding plants, it appears that prairie species grow well at levels of soil compaction that inhibit other plants. This may be related to their ability to grow under conditions of high atmospheric pressure and their apparent success in untilled soil in the second experiment.

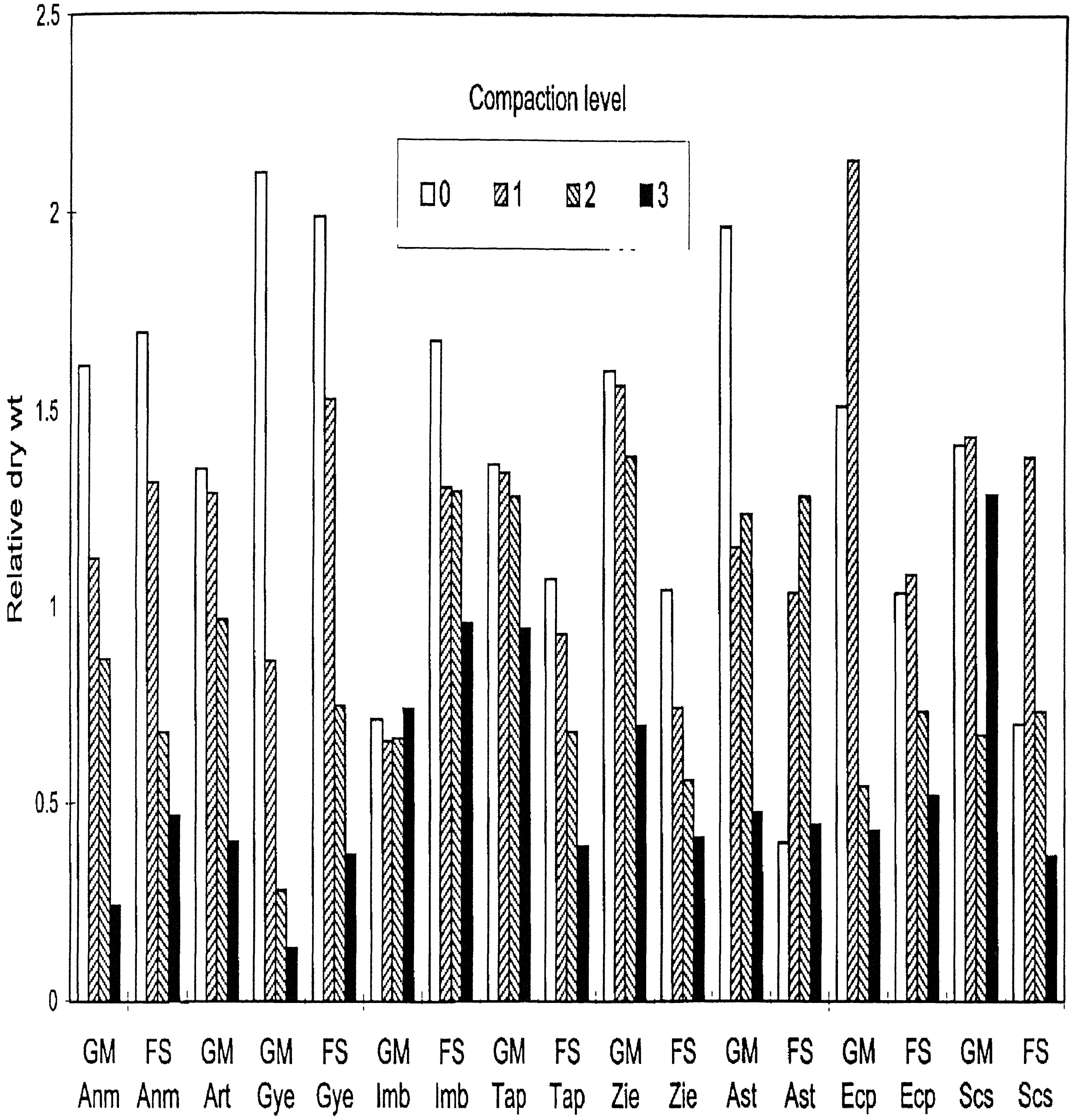

Figure 1. Dry weights (relative to average for species) of shoots of plants grown at different compaction levels in greenhouse medium (GM) or field soil (FS). Anm *Antirrrhinum majus,* Art *Arabidopsis thaliana,* Ast *Asclepias tuberosa,* Ecp *Echinacea purpurea,* Gye *Gypsophila elegans,* Imb *Impatiens balsamina,* Scs *Schizachyrium scoparium,* Tap *Tagetes patula,* Zie *Zinnia elegans.*

Table 3. Oxygen Concentrations for Half-Maximum Root Elongation (C_{05}) and Root Elongation at 1.14 MPa Relative to Controls at Atmospheric Pressure (0.1 MPa) for 10 Plant Species in Experiment 1.

Species	C_{05} (%)	Elongation (% of control)
Antirrhinum majus	2.34	41.3
Arabidopsis thaliana	0.97	61.3
Asclepias tuberosa	1.14	86.0
Echinacea purpurea	1.31	83.9
Gypsophila elegans	3.34	48.3
Impatiens balsamina	3.10	36.5
Monarda fistulosa	10.90	77.5
Schizachyrium scoparium	0.74	95.3
Tagetes patula	0.38	30.6
Zinnia elegans	4.98	32.9

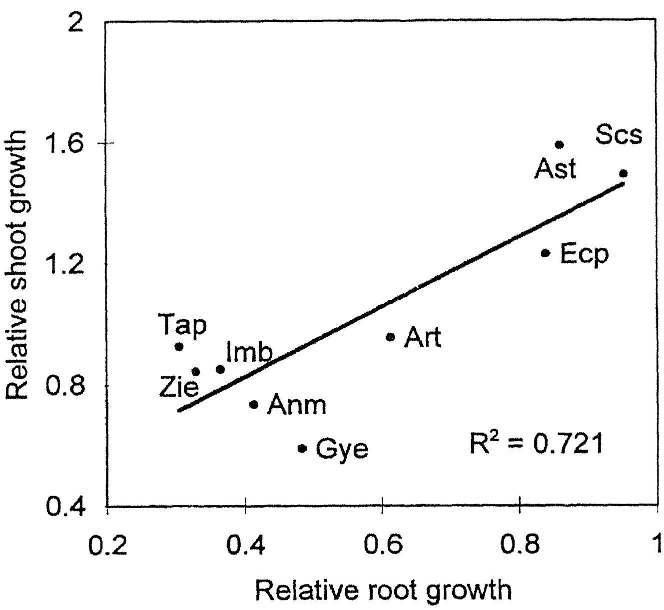

Figure 2. Correlation of shoot growth (dry weight relative to species average) with root elongation at 1.14 MPa, relative to 0.01 MPa for different plant species. See Figure 1 for key.

In the second season the plants have grown so that it has become more difficult to separate and estimate their areas in digital photographs. Further experiments involving destructive sampling and estimation of dry weight are underway to test some of these preliminary findings. More research is planned to investigate the environmental adaptations and landscape uses of prairie grasses and forbs.

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Table 4. Plant Areas Estimated from Digital Photographs for 13 Species of Seedlings Grown in Compacted and Uncompacted Media for 12 Weeks in the Greenhouse and Nine Species Six Weeks After Transplanting to the Field in Experiment 2.

Species	Area per Seedling (cm^2)			
	Seedling		After Transplanting	
	Uncompacted	Compacted	Uncompacted	Compacted
Allium cernuum	1.3	4.4	-	-
Anemone canadensis	8.0	7.7	-	-
Asclepias tuberosa	14.3	11.6	89	202
Eryngium yuccifolium	5.2	9.8	48	111
Liatris pycnostachya	23.7	23.6	55	92
Ratibida pinnata	21.9	30.6	343	340
Solidago speciosa	14.6	18.0	-	-
Tradescantia ohioensis	13.4	15.5	105	117
Vernonia fasciculata	27.1	45.2	-	-
Bouteloua curtipendula	20.2	25.9	277	361
Elymus canadensis	22.3	38.9	153	235
Schizachyrium scoparium	23.7	27.6	181	237
Spartina pectinata	12.0	29.4	309	387
(Probability of no compaction effect)	(0.0004)		(0.0001)	

Table 5. Average Areas from Digital Photographs of Nine Species of Plants Germinated in Different Media and After Transplanting to Tilled and Untilled Areas in Experiment 2.

Contrast	Transplants	6 Weeks	12 Weeks
Greenhouse mix	18.6	203	335
Topsoil	18.5	180	207
(Probability)	(0.940)	(0.057)	(0.0001)
Uncompacted	16.0	162	238
Compacted	21.6	225	293
(Probability)	(0.012)	(0.0001)	(0.0009)
Untilled	-	192	308
Tilled	-	190	221
(Probability)	-	(0.761)	(0.0001)

Postemergence Herbicide Efficacy on Crabgrass: 1997

John R. Street and Renee M. Stewart

Introduction

Postemergence crabgrass *(Digitaria spp.)* control for many years was primarily limited to organic arsenicals (MSMA, DSMA), which:

- Require repeat applications for effective postemergence crabgrass control.
- Are most efficacious on seedling crabgrass.
- Can cause some phytotoxicity to desirable turf grasses, especially in hot weather.

Acclaim has shown good-to-excellent efficacy for postemergence crabgrass control. However, some discoloration and stunting of Kentucky bluegrass may occur, and efficacy drops off under droughty (dry) soil conditions. Acclaim Extra, the new isomer of Acclaim, provides similar efficacy to Acclaim. Dimension also provides early postemergence crabgrass control.

Methods

Various herbicides and rates were evaluated for postemergence crabgrass control on an established stand of Kentucky bluegrass. The trial area was verticut in mid-April 1997 and over-seeded with one pound of crabgrass seed per 1,000 square feet (ft^2). In July 1997 herbicides were applied to crabgrass at two different stages of growth — early postemergence in the three- to five-leaf to one-tiller stage (Table 1) and late postemergence in the two- to four-tiller stage (Table 2).

Irrigation

Each herbicide treatment in both growth stages was irrigated:

- Within one hour after herbicide application (watered in).

Or:

- Irrigation was delayed for several days (not watered in).

All liquid applications were made with a CO_2-pressurized sprayer at 88 gpa.

Mowing Height

The Kentucky bluegrass stand was maintained at a mowing height of 0.75 inches until three weeks prior to herbicide treatment. A mowing height of 1.75 inches was maintained for the remainder of the postemergence study.

Nitrogen Application

An annual total of three pounds of actual nitrogen per 1,000 ft^2 was applied during the growing season. Irrigation was provided several times per week throughout the season to encourage crabgrass germination and seedling development. Treatments were replicated three times in a randomized

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complete block design with a plot size of 3' x 8'. Treatments were monitored for crabgrass control (percent crabgrass cover) at periodic intervals (seven to 10 days) after herbicide application. (See Tables 1 and 2 for information on early and late postemergence crabgrass control, respectively.)

Discussion

Acclaim

In previous Ohio State University research, Acclaim has exhibited good-to-excellent efficacy for postemergence crabgrass control up to the three- to four-tiller stage where soil moisture was adequate and crabgrass was not under stress. Efficacy has been found to drop off dramatically under droughty (dry) soil conditions, sometimes causing erratic and variable results in the field. Efficacy is significantly reduced when Acclaim is used in combination with phenoxy herbicides, such as 2,4-D.

Acclaim is a foliar-absorbed herbicide, making adequate foliar coverage essential. This entails the following:

- Mowing prior to treatment to open the canopy for maximum contact of liquid spray with crabgrass foliage, and
- Spraying with sufficient water volume and proper nozzles to assure good foliar coverage.

The authors' research showed stunting and discoloration of Kentucky bluegrass may occur after most applications during the early season, when bluegrass is rapidly growing. This research also showed that Acclaim applications severely discolor bentgrass. As a result, the authors recommend light, multiple applications (see the label). Iron and/or nitrogen will help mask the discoloration symptoms without any negative effect on efficacy. The recommended rate range for Acclaim is 0.12 to 0.25 lbs. ai/A (active ingredient per acre), the higher rate targeted for more mature crabgrass.

The authors' research showed Acclaim's activity rate to be moderate: Crabgrass kill typically occurs in two to three weeks. Three to five days after herbicide application, crabgrass turns orange or purple, a color response that lasts for seven to 10 days. Eventual browning and necrosis occur over a total period of two to three weeks.

Acclaim Extra (fenoxyprop p-ethyl)

This new isomer formulation of Acclaim also provides good-to-excellent control of crabgrass in postemergence treatments at rates ranging from 0.06 to 0.125 lbs. ai/A. In 1997, Acclaim Extra provided good-to-excellent efficacy of crabgrass both early (Table 1) and late (Table 2) postemergence at 0.06 and 0.09 lbs. ai/A rates. More consistent and reliable control of mature tillered crabgrass occurs at the upper end of the rate recommendation range of 0.06 to 0.125 lbs. ai/A. The fenoxyprop herbicides are foliar-absorbed materials. Therefore, it is not surprising that irrigation shortly after application significantly reduces efficacy (see Tables 1 and 2, *Watered In* column). The authors' research showed no noticeable difference in the rate of crabgrass kill between Acclaim 1EC and Acclaim Extra.

Preclaim

(3.09 EC; American Cyanamid premix formulation of Acclaim Extra and pendimethalin)

In general, Preclaim has provided similar efficacy to Acclaim Extra alone for postemergence crabgrass control. As a premix formulation of pre- and post-herbicide products, it provides a wider window for preemergence herbicide applications in the spring. In 1997 Preclaim provided good-to-excellent efficacy on crabgrass in both the early and late postemergence trials at rates of 2.06 to 3.09 pounds ai/A (Tables 1 and 2). Preclaim activity at the 1.545 lbs. ai/A rate was good and fair/poor in the early and late postemergence stages, respectively. When watered in shortly after herbicide application, Preclaim activity for postemergence crabgrass control was significantly reduced.

Dimension (dithiopyr)

Dimension is a relatively new commercial herbicide that exhibits both pre- and postemergence herbicide activity on crabgrass. Dimension, therefore, provides a wider window for application of preemergence herbicides in the spring. Postemergence activity of Dimension is slow. Total kill typically ranges from three (untillered crabgrass) to five weeks (tillered crabgrass). Dimension does, however, stunt crabgrass in 10 to 14 days, making its presence in the turfgrass canopy less noticeable. The stunted crabgrass is initially hidden within the canopy, then eventually dies over a period of three to five weeks. During the stunting phase, crabgrass turns yellow, then purple, and is followed by necrosis.

In 1997, **Dimension 2EC** provided good to excellent early postemergence control of crabgrass at the 0.38 to 0.50 lbs. ai/A rates (Table 1). Dimension 0.164FG (AD 445) also provided good to excellent early postemergence crabgrass control at the highest rate of 0.5 lbs. ai/A. Lower rates of Dimension 0.164 FG were not as efficacious as equivalent rates of Dimension 2EC.

The authors' past research has shown that Dimension EC, G, and FG formulations generally do not differ in postemergence crabgrass efficacy, except for a slightly slower activity rate with G and FG formulations. In 1997, all formulations and rates of Dimension exhibited significantly poorer late postemergence crabgrass efficacy compared to early postemergence activity (Tables 1 and 2). These efficacy results are consistent with efficacy data from past early and late postemergence trials at Ohio State University. These results characterize Dimension as a good to excellent early postemergence crabgrass herbicide and a poor late postemergence crabgrass herbicide.

Root absorption is considered to be the principle uptake mechanism for the preemergence activity of Dimension. It was hypothesized that irrigation shortly after Dimension application to move the herbicide to the soil root zone might improve either the overall efficacy and or the rate of activity. Irrigation did not appear to have any significant negative or positive effect on the overall activity or efficacy of Dimension postemergence (Tables 1 and 2).

Combinations of Dimension with Daconate (MSMA) in previous Ohio State University research have been shown to increase the rate of crabgrass kill and to enhance efficacy. Dimension 1EC rates of 0.25, 0.38, and 0.30 lbs. ai/A in combination with 1.0, 0.50, and 0.25 lbs. ai/A rates of Daconate 6F, respectively, have proved effective in enhancing the efficacy and rate of Dimension activity. Dimension in combination with Daconate is not extremely effective beyond the three- to four-tiller stage. It may cause stunting of crabgrass, but kill may not occur.

Drive (quinclorac)

Drive is an excellent postemergence crabgrass herbicide. BASF continues to have an interest in acquiring a turfgrass label for this product. Liquid and granular formulations of Drive will be evaluated in 1998. Previous Ohio State University research has shown that Drive typically kills crabgrass in seven to 10 days or less at rates of 0.25 to 0.75 lbs. ai/A. Drive has also provided excellent efficacy of mature crabgrass at rates of 0.5 to 0.75 ai/A. Unlike Acclaim, Drive efficacy does not appear to be as sensitive to soil moisture.

In 1997, Drive exhibited good-to-excellent efficacy on crabgrass in the early postemergence stage (Table 1) and excellent efficacy in the late postemergence stage at rates of 0.50 and 0.75 lbs. ai/A. Crabgrass browning and kill occurred within a week after herbicide application. Drive activity rate was similar between early and late postemergence applications. It is important that an adjuvant (0.50% by volume) be used with the Drive 75 DF formulation. These results on both efficacy and activity rate are consistent with Drive research at Ohio State for the past five years. Drive is considered to have both foliar and root activity and is used in some crops preemergence. Surprisingly, Drive efficacy was significantly reduced where irrigation occurred shortly after herbicide applications (Tables 1 and 2).

Table 3 provides a ranking of the relative activity rate and specific activity rate of the four postemergence crabgrass herbicides discussed based upon five years of Ohio State University research.

Table 1. Efficacy of Herbicides Applied Early Postemergence for Crabgrass *(Digitaria)* Control.

			Crabgrass Cover (%)[a]								
				Not Watered In[c]				Watered In			
Herbicide[b]	Formulation[d]	Rate (lbs.ai/A)	7/25[e]	8/3	8/8	8/20	9/5	8/3	8/8	8/20	9/5
Dimension	2 EC	0.25	50.0	40.0	26.7	18.3	16.7	60.0	60.0	40.0	28.3
Dimension	2 EC	0.38	50.0	40.0	20.0	6.7	5.0	63.3	63.3	28.3	15.0
Dimension	2 EC	0.50	50.0	40.0	16.7	5.0	3.0	63.3	63.3	28.3	6.7
Dimension AD 445	0.164 FG	0.25	53.3	43.3	33.3	30.0	33.3	63.3	63.3	21.7	18.3
Dimension AD 445	0.164 FG	0.38	53.3	40.0	21.7	13.3	13.3	60.0	50.0	13.3	10.0
Dimension AD 445	0.164 FG	0.50	53.3	40.0	13.3	5.0	2.0	56.7	46.7	5.0	1.3
Acclaim Extra	0.57 EW	0.06	53.3	33.3	13.3	10.0	3.0	50.0	40.0	20.0	20.0
Acclaim Extra	0.57 EW	0.09	53.3	40.0	6.7	0.0	0.0	50.0	46.7	8.3	8.3
Drive	75 DF	0.25	50.0	4.0	0.0	5.0	10.0	41.7	31.7	31.7	36.7
Drive	75 DF	0.50	50.0	0.0	0.0	0.0	0.0	46.7	40.0	26.7	28.3
Drive	75 DF	0.75	50.0	0.0	0.0	0.0	0.0	40.0	30.0	26.7	25.0
Preclaim	3.09 EC	1.545	50.0	40.0	30.0	10.0	6.7	53.3	50.0	40.0	20.0
Preclaim	3.09 EC	2.06	50.0	40.0	21.7	5.0	0.7	53.3	51.7	30.0	13.3
Preclaim	3.09 EC	3.09	50.0	40.0	15.0	2.0	0.0	50.0	46.7	23.3	5.0
Daconate	6 F	2.0	53.3	36.7	23.3	16.7	20.0	60.0	60.0	50.0	50.0
Untreated	—	—	53.3	63.3	66.7	68.3	73.3	60.0	66.7	68.3	73.3
LSD (0.05)			5.99	7.34	6.57	4.61	4.63	8.31	10.80	7.16	4.79

[a] Crabgrass cover is reported as percent crabgrass per plot averaged over three replications.
[b] Postemergence applications were made on July 25, 1997, when crabgrass was in the three- to five-leaf to one-tiller stage.
[c] Applications were watered in within one hour after application (watered in) or irrigation was delayed for several days (not watered in).
[d] Liquid applications were made at two gallons per 1,000 square feet using a CO_2-pressurized sprayer with a flat fan nozzle.
[e] Crabgrass population/cover prior to herbicide application averaging 65–70%.

Table 2. Efficacy of Herbicides Applied Late Postemergence for Crabgrass *(Digitaria)* Control.

			Crabgrass Cover (%)[a]								
				Not Watered In[c]				Watered In			
Herbicide[b]	Formulation[d]	Rate (lbs.ai/A)	7/25[e]	8/3	8/8	8/20	9/5	8/3	8/8	8/20	9/5
Dimension	2 EC	0.25	73.3	73.3	73.3	56.7	33.3	73.3	60.0	60.0	40.0
Dimension	2 EC	0.38	73.3	73.3	73.3	56.7	30.0	73.3	66.7	66.7	30.0
Dimension	2 EC	0.50	70.0	70.0	70.0	50.0	18.3	70.0	63.3	63.3	26.7
Dimension AD 445	0.164 FG	0.25	66.7	66.7	66.7	56.7	40.0	66.7	66.7	63.3	40.0
Dimension AD 445	0.164 FG	0.38	73.3	73.3	73.3	63.3	30.0	73.3	73.3	66.7	36.7
Dimension AD 445	0.164 FG	0.50	73.3	73.3	73.3	53.3	16.7	73.3	73.3	56.7	26.7
Acclaim Extra	0.57 EW	0.06	66.7	56.7	21.7	10.0	11.7	66.7	53.3	33.3	30.0
Acclaim Extra	0.57 EW	0.09	70.0	60.0	11.7	3.3	5.0	70.0	50.0	18.3	16.7
Drive	75 DF	0.25	63.3	10.0	10.0	18.3	26.7	63.3	53.3	53.3	80.0
Drive	75 DF	0.50	63.3	0.0	0.0	1.3	2.0	63.3	43.3	43.3	70.0
Drive	75 DF	0.75	66.7	0.0	0.0	0.0	0.0	66.7	40.0	40.0	56.7
Preclaim	3.09 EC	1.545	70.0	63.3	43.3	20.0	20.0	70.0	60.0	43.3	33.3
Preclaim	3.09 EC	2.06	73.3	63.3	36.7	11.7	10.0	73.3	60.0	33.3	18.3
Preclaim	3.09 EC	3.09	70.0	50.0	13.3	3.0	3.0	70.0	53.3	16.7	13.3
Daconate	6 F	2.0	66.7	50.0	20.0	5.0	5.0	66.7	56.7	46.7	63.3
Untreated	—	—	73.3	73.3	73.3	76.7	80.0	73.3	73.3	80.0	83.3
LSD (0.05)			10.02	11.58	10.02	8.58	5.08	10.0	7.33	8.38	6.47

[a] Crabgrass cover is reported as percent crabgrass per plot averaged over three replications.
[b] Postemergence applications were made on July 25, 1997, when crabgrass was in the two- to four-tiller stage.
[c] Applications were watered in within one hour after application (watered in) or irrigation was delayed for several days (not watered in).
[d] Liquid applications were made at two gallons per 1,000 square feet using a CO_2-pressurized sprayer with a flat fan nozzle.
[e] Crabgrass population cover prior to herbicide application averaging 65–70%.

Table 3. Postemergence Herbicide Efficacy Active Ranking.

Herbicide	Common Name	Relative Activity Rate	Specific Activity Rate*
Dimension	dithiopyr	slow	3 to 5 weeks
Acclaim	fenoxyprop ethyl	moderate	2 to 3 weeks
Acclaim Extra	fenoxyprop p-ethyl	moderate	2 to 3 weeks
Drive	quinclorac	rapid	7 to 10 days

* Specific activity rate based on time to browning and total necrosis/kill.

Important Considerations When Changing to a New Soil Testing Laboratory

Mary Ann Rose

Summary

With the closing of The Ohio State University's Research-Extension Analytical Laboratory (REAL), former clients will have to find new providers of soil, growing media, plant tissue, and water analyses. This article is a guide to some of the differences in analytical procedures and methods of reporting that may be encountered when switching to a new lab.

Introduction

After many years of serving Ohio's agricultural industry, the Research-Extension Analytical Laboratory (REAL) at Ohio State University closed at the end of 1998. The REAL lab had provided testing services for soil, media, plant tissue, feed, manure, and compost.

The most common tests used by the nursery industry included the soil, soilless mix, plant tissue, and water analyses. Growers and landscapers who find themselves switching from one testing laboratory to another can expect to see differences in the way results are expressed (and interpreted) and perhaps in the types of tests that are used. It is possible that test results from a new lab may require an entirely different set of interpretive guidelines. A testing lab should provide appropriate guidelines with its test results, although the guidelines may not be specifically geared to nursery crops. Your Ohio State University Extension agent also can help interpret results if you switch to a new lab. This article is a guide to the types of changes that may be encountered when switching labs.

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Testing Procedures

The Mineral Soil Test

The standard soil test provided by the REAL laboratory included a lime recommendation (if needed); available phosphorus (P); exchangeable calcium (Ca), magnesium (Mg), and potassium (K); base saturation for Ca, Mg, and K; and the cation exchange capacity (CEC). Most labs in the Midwest are probably using the same or similar tests for these values; however, the units in which they express the values may vary.

For example, the REAL lab had recently switched over to using ppm (parts per million) instead of lb./A (pounds per acre) to express available P and exchangeable Ca, Mg, and K. If you change from the REAL lab to a commercial lab using lb./A, expect to see these soil test values *double,* since 1 ppm = 2 lb./A. A third unit that is sometimes used to express exchangeable Ca, Mg, and K is milliequivalents per 100 grams (meq/100g). Somewhat more complex computations are required to convert meq/100g to lb./A.

Soil soluble salts (EC) is a special soil test that is useful if over-fertilization or de-icing salt problems are suspected. It is particularly confusing to compare this test between labs, because EC may be expressed several different ways. The REAL lab used mhos x 10^{-5}/cm (for the soil test, but not for the soilless test). Most labs use millimhos/cm. The difference is a factor of 100. For example, 100 mhos x 10^{-5}/cm = 1 millimhos/cm.

The Soilless Mix Test

The soilless test is the appropriate choice for most container media used today, even if they contain a small percentage of soil. Soilless tests provide pH, nitrate-N, soluble salts (EC), P, K, Ca, Mg, and some micro-elements, typically iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn). Labs may also provide ammonium-N, chloride, fluoride, sulfate-S, boron, molybdenum, and sodium as part of a standard test package.

Most labs are using the saturated medium extract procedure (SME), although some may be using a 1:2 soil-water dilution procedure. The same sample extracted by the SME method can be expected to have nutrient values approximately double those from the 1:2 dilution method, because less diluent (water) is used in the SME. With one exception, results from different labs that use the same dilution procedure (either SME or 1:2) should be very similar. Micronutrients can vary, however, because some labs (including the REAL lab) use a chelating agent (DTPA) when extracting media for micronutrients. Use of the chelating agent results in higher micronutrient test values than the water-only extraction procedure, and different interpretive guidelines should be used.

Plant Tissue Tests

A plant tissue test (most commonly leaves) reflects the elemental content of the tissue. The whole tissue, not an extract, is tested; thus results will not vary among labs because of different extraction procedures. Labs may use different types of equipment to perform the analyses, but the same sample submitted to different labs should nonetheless produce very similar results.

Nitrogen content of plant tissue can vary somewhat between labs because of two fundamentally different methods of determination; however, even in this case, the difference is not more than a few tenths of a percent. Tissue concentrations of macro-elements (N, P, K, Ca, and Mg) are usually expressed as percent by dry weight of tissue, and the microelements (Fe, Cu, Mn, Zn, B, and so forth) are expressed in ppm.

Water Tests

An irrigation water analysis usually provides all or most of the following — pH, alkalinity, soluble salts, nitrate-N, ammonium-N, P, K, Ca, Mg, Fe, sulfate-S, Mn, Zn, Cu, B, Cl, F. As with plant tissue-testing, results from lab to lab should be similar, because no extraction process is used. All elements are expressed in ppm. Alkalinity is the only parameter in a water test that may be expressed differently between laboratories. The REAL lab expressed alkalinity as ppm of calcium carbonate, whereas some labs use ppm bicarbonate. To convert from one to the other:

1.2 x ppm $CaCO_3$ = ppm HCO_3^-

Testing Laboratories

Table 1 contains a list of laboratories that perform one or more types of analytical procedures. This list is offered as a reference to growers and landscapers, but no endorsement of any lab is implied.

When choosing a lab, considerations include not only cost, but also turnaround time, lab reputation, and attention to accuracy and precision. Granted, there is no easy way for a prospective client to judge the latter characteristics. But if lab representatives are able to intelligently discuss testing procedures and offer interpretive advice, this is a good sign.

Table 1. Regional Soil Test Labs That Also May Provide Media, Water, and Tissue Testing.

Lab	Location	Telephone No.
Agricultural Analytical Services Laboratory (Pennsylvania State University)	State College, PA	814-863-4540
Alloway Testing	Mansfield, OH	419-535-1644
A & L Great Lakes Lab	Fort Wayne, IN	219-483-4759
Brookside Labs	New Knoxville, OH	419-753-2488
CLC Labs	Westerville, OH	614-888-1663
Calmar Lab	Westerville, OH	614-523-1005
Countrymark/Land O'Lake	Indianapolis, IN	317-685-3000
Holmes Lab	Millersburg, OH	800-344-1101
Na-churs	Marion, OH	800-622-4877
Scotts Testing Laboratory*	Allentown, PA	800-743-4769
Spectrum Analytical	Washington Courthouse, OH	800-321-1562
Woodsen-Tenent	Dayton, OH	937-222-4179

* Provides media testing, but not soil testing

Abstracts

Seasonal Patterns of Nutrient and Dry Weight Accumulation in Freeman Maple

Mary Ann Rose and Barbara Biernacka
The Ohio State University Department of Horticulture and Crop Science
In Press. *HortScience.*

Abstract. Seasonal patterns of N, P, and K accumulation and remobilization in Freeman maple (*Acer* x *freemanii* E. Murr. 'Jeffersred') were studied to guide future improvements in fertilization efficiency. Leaves, stems, and roots of container-grown trees were harvested over a 12-month period (June–June) in each of two experiments. Plants were fertilized from June to October with three rates of soluble fertilizer (50, 100, and 200 mg L^{-1} N). Fertilizer rate had linear and quadratic effects on dry weight and nutrient contents but did not affect seasonal accumulation patterns. Whole-plant nutrient contents and dry weights increased until mid-October, prior to leaf abscission. The largest fraction of nutrients and dry weights were allocated to leaves until early September. Between September and October, the most rapid accumulation of N, P, and dry weight occurred in root tissue. Highest nitrogen recovery efficiency occurred in late summer (Experiment 2) or early fall (Experiment 1). There was no statistically significant evidence for N, P, or K resorption in the fall, but evidence of N remobilization (not P or K) in the spring was very strong. Whole-plant dry weight doubled between April and June, while ~50% of the N stored in woody tissues was translocated to new shoots.

A Comparison of Micronutrient Sources for Container *Rhododendron*

Mary Ann Rose and Hao Wang
The Ohio State University Department of Horticulture and Crop Science
In Press. *HortTechnology.*

Abstract. Micronutrient supplements were applied to container *Rhododendron* 'Girard Scarlet' in three forms — uncoated micronutrient fertilizer; slow-release, NPK-plus-minors fertilizer; and biosolids compost (15% v/v). Control plants received no supplement. While all micronutrient treatments had significantly higher foliar Mn or Cu concentrations than controls one year after potting, these concentrations did not increase growth (dry weight) or plant quality. One, three, and 12 months after potting, the compost treatment had significantly higher diethylenetriaminepentaacetic acid (DTPA)-extractable levels of Mn, Fe, and Zn in the medium. Only one of six micronutrient fertilizer treatments increased extractable micronutrient concentrations (Cu) on all testing dates. Correlations be-

tween medium-extractable and foliar micronutrient concentrations were low ($r^2 < 0.30$). Vigorous growth in the control treatment suggested that adequate levels of micronutrients were supplied by the pine-bark/hardwood-bark/peat/sand medium. September concentrations [ppm (mg L^{-1})] as low as 2.0 Mn, 17.8 Fe, 0.3 Cu, 4.2 Zn, and 0.9 B in DTPA extracts produced acceptable growth in *Rhododendron* through the following June.

Fertilizer Concentration and Moisture Tension Affect Growth and Foliar N, P, and K of Two Woody Ornamentals

Mary Ann Rose and Hao Wang
The Ohio State University Department of Horticulture and Crop Science
In Press. *HortScience.*

Abstract. Crabapple *[Malus* x *zumi* (Rehd.) 'Calocarpa'] and maple *(Acer* x *freemanii* E. Murray 'Jeffersred') trees were grown in containers from June 22 to Oct. 3 with three fertilizer concentrations (50, 100, and 200 mg L^{-1} N) and two levels of moisture tension in the medium [low setpoint (moist) = 5 kPa and high setpoint (dry) = 18 kPa]. Whole-plant growth was enhanced more by minimizing water stress than by increasing fertilizer concentration. Shoot length and whole-plant dry weight were greater (> 29% for crabapple and > 90% for maple) in low-tension treatments (low water stress) but were unaffected by fertilizer concentration. Moisture tension also had a dominant effect on dry weight allocation to leaves, stems, and roots. In contrast, foliar nutrient concentrations increased with fertilizer concentration but were affected to a lesser degree by moisture tension. Seasonal patterns in biomass allocation were little affected by treatments; the largest proportions of leaf and root biomass accumulated during summer and fall, respectively.

$CuSO_4$ Filters Influence Flowering of Chrysanthemum cv. Spears

Margaret McMahon
The Ohio State University
In press. *Scientia Hort.*

Abstract. 'Spears' chrysanthemums *(Dendranthema* x *grandiflorum* [Ramat.] Kitamura) were grown under solar filters filled with $CuSO_4$ in solution which absorbs far-red (FR), or water, which does not absorb FR, and were exposed to marginally long natural photoperiods, artificially long photoperiods, or artificially short photoperiods. Internode length and plant height were reduced under $CuSO_4$ filters compared to plants grown under water filters, regardless of photoperiod. Plants grown under water- or $CuSO_4$-filled filters that received artificial short days flowered seven days ahead of plants grown in natural, marginally long photoperiods under $CuSO_4$ filters and 17 days ahead of plants grown under water filters and receiving natural, marginally long photoperiods. The number of nodes was the same for plants grown in short and marginally long days under $CuSO_4$ filters and in short days under water filters, indicating flower induction occurred simultaneously in these treatments. Development of additional nodes on plants under water-filled filters and receiving natural long-days indicated that floral induction was delayed. A cool white fluorescent light night break prevented or delayed flowering of plants grown under

water- and $CuSO_4$-filled filters during natural short days. The results demonstrate that standard practices of photoperiodic control can be used to time chrysanthemums 'Spears' grown under $CuSO_4$ filters for pot mum production.

Far-Red Absorbing Filters Influence Growth and Development of *Euphorbia pulcherrima* 'Glory'

M. J. McMahon
The Ohio State University
J. W. Kelly
Clemson University
Plant Growth Reg. Soc. Quarterly

Abstract. Plants of poinsettia (*Euphorbia pulcherrima* Willd. ex Klotzsch) 'Glory' were grown in chambers fitted with double-walled polycarbonate panels filled with light-filtering solutions of a blue dye, a 6% (w:v) $CuSO_4$ $5H_2O$, and water (control) that altered the ratio of red (R) to far-red (FR) light to 1.00, 3.33, and 1.16, respectively. Plants grown under $CuSO_4$-filters were shorter (32%) with shorter internodes (48%) than control plants. Leaf chlorophyll was 56% greater in $CuSO_4$-grown plants compared to control. Plants from all treatments flowered at the same time when placed in the chambers during inductive short-day photoperiods (year one). Plants flowered two weeks earlier under $CuSO_4$ filters compared to controls when placed in the chambers during noninductive photoperiods (year two). Far-red-absorbing filters have the potential to become a useful plant growth tool.

Irrigation Management Practices in Ohio

Cassandra C. Brown and Mary Ann Rose
The Ohio State University Department of Horticulture and Crop Science

Expanding urbanization in Ohio has made the availability of quality water an emerging issue of great importance to the state's nursery industry. This development necessitates an examination of nurseries' use and management of water. This study surveyed 600 Ohio nursery growers with a mail questionnaire to determine the frequency of irrigation and water-saving techniques across the state. The 21-question questionnaire covered topics including water sources, irrigation practices, water testing, and information needs. The mailing list used was the Ohio Department of Agriculture's licensed nursery operators list. Nonrespondents received a postcard reminder and a second copy of the survey within three months of the initial mailing, yielding a 45% response rate. Data were analyzed using SPSS software. Responses indicate that approximately 57% of Ohio nurseries used irrigation in the 1997 growing season. For field production, 64% of nurseries used overhead irrigation for at least half of their irrigated production; for container production, 91%. Nearly 41% of respondents using irrigation reported capturing runoff for reuse this past year. The most common irrigation sources for Ohio nurseries were wells (79%) and ponds (62%). Additional goals for the project included raising awareness of water-management and water-quality issues, identifying common water-quality problems, and obtaining direction for future research and extension efforts.

Expand Your Web of Knowledge: Internet Resources for the Green Industry

The Ohio State University's College of Food, Agricultural, and Environmental Sciences offers a number of academic resources through the Internet or World Wide Web. These sources provide easy access to a vast array of helpful information. The web addresses to access these sources are presented here.

The Ohio State University College of Food, Agricultural, and Environmental Sciences

College of Food, Agricultural, and Environmental Sciences
http://www.hcs.ohio-state.edu/faes/faes.html

Internet Tutorials
http://www.hcs.ohio-state.edu/faes/internet/internet.html

Scholarship Opportunities
http://www.hcs.ohio-state.edu/faes/awards/awards.html

Jobs Database
http://www.hcs.ohio-state.edu/faes/career/jobsearch.html

Resume Database
http://www.hcs.ohio-state.edu/faes/career/resumesearch.html

Degree Programs
http://www.hcs.ohio-state.edu/faes/degree/degree/html

Project Reinvent
http://www.hcs.ohio-state.edu/faes/reinvent.html

Alumni Society
http://www.hcs.ohio-state.edu/faes/alumni.html

Horticulture and Crop Science in Virtual Perspective

Horticulture and Crop Science (HCS) in Virtual Perspective
http://www.hcs.ohio-state.edu

HCS Homepage
http://www.hcs.ohio-state.edu/hcs/hcs.html

Online Courses
http://www.hcs.ohio-state.edu/hcs/TMI/Online_Courses.html

National Horticulture Internship Database
http://www.hcs.ohio-state.edu/hcs/Ed/Interns.html

Web Garden
http://www.hcs.ohio-state.edu/webgarden.html

Factsheet Database
http://www.hcs.ohio-state.edu/factsheet.html

Plant Dictionary
http://www.hcs.ohio-state.edu/plants.html

Buckeye Yard and Garden onLine
http://www.hcs.ohio-state.edu/bygl.html

Weekly Gardening News for Central Ohio
http://www.hcs.ohio-state.edu/wgn.html

Ohio Master Gardener Program
http://www.hcs.ohio-state.edu/mg/mg.html

Landscape and Nursery Dialogue
http://www.hcs.ohio-state.edu/hcs/webgarden/Land/Land.html

Horticulture Search Engine
http://www.hcs.ohio-state.edu/hcs/searchworld.html

Ohio State University Extension

Ohio State University Extension
http://www.ag.ohio-state.edu

OhioLine
http://www.ag.ohio-state.edu/ohioline

VegNet
http://www.ag.ohio-state.edu/~vegnet

Floriculture Newsletter
http://www.ag.ohio-state.edu/~flori

Plant Pathology
http://www.ag.ohio-state.edu/~plantdoc

For Additional Information

Follow-up questions can be directed to Dr. Tim Rhodus at The Ohio State University's Department of Horticulture and Crop Science.

Phone: 614-292-3871
E-mail: rhodus.1@osu.edu

Ohio State University Publications Recommended for the Green Industry

Ohio Agricultural Research and Development Center (OARDC) Publications

Nitrogen Fertilization of Canaan Valley Seed Source of Balsam Fir.
Special Circular 159. 1998. James H. Brown.

The Ohio Christmas Tree Industry: Who Are We and Where Are We Going?
Special Circular 158. 1998. Randall B. Heiligmann and Gregory R. Passewitz.

Ornamental Plants: Annual Reports and Research Summaries.
Special Circular 152. 1996. Mary Ann Rose and James A. Chatfield, Editors.

Ornamental Plants: Annual Reports and Research Reviews.
Special Circular 154. 1997. Mary Ann Rose and James A. Chatfield, Editors.

Ornamental Plants: Annual Reports and Research Reviews.
Special Circular 157. 1998. Mary Ann Rose and James A. Chatfield, Editors.

Taxus and Taxol Research.
Special Circular 150. In press. Robert Hansen.

Turfgrass Research Report.
Special Circular 153. 1995. D. Shetlar, Editor.

Turfgrass Research Report.
Special Circular 155. 1997. D. Shetlar, Editor.

For copies and information on other available OARDC publications, write to:

Publications Distribution Center
The Ohio State University
Ohio Agricultural Research and Development Center
1680 Madison Avenue
Wooster, Ohio 44691-4096

Ohio State University Extension Publications

Controlling Weeds in Nursery and Landscape Plantings.
Ohio State University Extension Bulletin 867. 1998. L. Kuhns, T. Harpster, M. Rose, and S. Guiser.

This 48-page bulletin provides weed control recommendations and a detailed discussion of herbicides currently labeled for landscape and nursery.

Disease Control in the Landscape.
Ohio State University Extension Bulletin 614. 1997. C. Ellet, M. Ellis, S. Nameth, H. Hoitink, N. Taylor, J. Rimelspach, J. Chatfield, M. Rose, and D. Shetlar.

This 82-page color bulletin includes a discussion of plant-health management and diagnosis of plant-health problems. Numerous color photographs and text help the reader recognize symptoms of specific landscape plant diseases.

Herbicide Mode of Action and Injury Symptoms.
NCR 377. 1992.

This 17-page bulletin explains modes of action, and 43 color photos help the reader identify injury symptoms.

Horticultural Crisis Situations.
Bulletin 748. 1978. Multiple authors from Ohio State University's Department of Horticulture and Crop Science.

This bulletin suggests actions for crisis situations including low- and high-temperature injury, storms, flooding, and pollution injury. Landscape plants, fruits, and vegetables are considered.

Identifying Noxious Weeds of Ohio.
Ohio State University Extension Bulletin 866. 1998. M. Rose and C. Sheaffer.

A 23-page color bulletin designed to aid in the identification of weeds on the Ohio Department of Agriculture's noxious weed list.

Insect and Mite Control on Woody Ornamentals and Herbaceous Perennials, 1997–1998.
Ohio State University Extension Bulletin 504. D. Shetlar and D. Herms.

This 73-page bulletin contains tables of pesticide information regarding insect and mite control on numerous plants, as well as a discussion of integrated pest management and alternative products.

The Native Plants of Ohio.
Ohio State University Extension Bulletin 865. 1998. C. Sheaffer and M. Rose.

This bulletin includes a discussion of the natural history of Ohio and how native plants can be used in the landscape. Reference tables of woody and herbaceous native species provide information on plant features, preferred habitat, distribution in Ohio, and availability in the trade.

Ohio Christmas Tree Producers Manual.
Bulletin 670. J. Brown, W. Cowen, and R. Heiligman.

Details on selection and evaluation of planting sites, species and seed source selection, proper planting, weed control, fertilizer, pest control, and shearing and shaping.

Ohio Pond Management.
Bulletin to be available in spring 1999.

A comprehensive guide to site selection, physical and chemical properties of pond water, aquatic herbicides, controlling weeds, stocking, and maintaining healthy fish populations. Includes 29 drawings.

For copies of these and other Extension publications, inquire at the Ohio State University Extension office in your county.

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